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THE LIFE-HISTORIES OF DECAPOD CRUSTACEA FROM MADRAS

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INTRODUCTION.

This paper embodies a part of the result of a systematic study of the Madras plankton with special reference to Decapod larvae, undertaken by me as a research student of the Madras University, in order to follow the metamorphoses of some of the common Decapod crustaceans of this coast. The work was taken up at the suggestion of Prof. R. Gopala Ayyar, Honorary Director of the University Zoological Laboratory, and is, more or less, the outcome of the work on the plankton of this coast done by a former research student (Madras Plankton by K. S. Menon—Records of the Indian Museum, Vol. XXXIII, Part IV). I am greatly indebted to Prof. Gopala Ayyar for the great help and encouragement I have received from him, and I should like to take this opportunity to tender him my grateful thanks. I should also thank Dr. F. H. Gravely, Superintendent of the Madras Museum, for kindly going through the paper and for giving me several helpful suggestions. My thanks are also due to the University of Madras for enabling me to do this work by awarding me a studentship.

Occurrence.—Though Decapod larvae are hardly ever absent from the plankton there is a considerable fall in their number in the hottest months of the year, viz., May, June, July and August. During these months each day's townet collection yielded only a few larvae belonging mostly to Anomuran or Brachyuran forms. Larvae of Macrurous Decapods were practically absent in the plankton during these months. *Lucifer* is an exception, its larvae in various stages being present in July and August as well as in other months; they have not, however, been seen in May or June. Larvae of a few Pagurid species which have not yet been identified were present throughout the year in varying numbers, and a number of Pagurid larvae were invariably present in the collections made during May, June, July and August, the first post-larval stages or glaucothoes being quite common in July and August.

The period in which Decapod larvae are particularly abundant is that immediately following the monsoons, viz., the end of November and the four following months. During this period large numbers of larvae belonging to a variety of forms are always present and often in the same collection numerous individuals of the same form belonging to different stages occur. Larval forms of the same species, however, do not occur all through the period. In fact, with the exception of a few forms like *Acetes*, *Hippa*, *Lucifer* and some species of *Pagurids* all others observed occur for short periods and then disappear. An example in point is a species of *Callianassa,* the development of which is described below. Its larvae are conspicuous objects of the townet collections and were present, though not in large numbers, in December and January and totally disappeared during the rest of the

period. It is not possible to give more definite information regarding the periods of occurrence of the various families, as such a detailed study was not attempted.

Collections of the plankton were generally made not very far from the shore, the distance varying from 2 to 3 miles. The larvae that occur in these collections are mostly of those forms which live near the shore. On certain days swarms of larvae of some forms like *Acetes*, *Penaeus* and *Hippa* in various stages of development were captured. This abundance, however, was not observed in the case of most of the Anomuran and Brachyuran forms. Robert Gurney (Report on the Decapod Larvae of the British Antarctic "Terra Nova" Expedition, 1924) observed the same phenomenon in some of the plankton collections of the Antarctic Expedition examined by him and explains it by assuming that these larvae are not so much at the mercy of wind and waves as they are usually believed to be, but that they have got the power of remaining together in spite of forces tending to separate them.

Method.—One great difficulty was experienced in attempting to study the development of these forms, namely, that of getting the earliest larval stages hatched out in the laboratory. Though numerous female crabs with mature eggs were obtained, in not a single case was it found possible to get the eggs to hatch. One of these specimens, from the eggs of which fully developed embryos showing signs of life were extracted, continued to live in the aquarium for a number of days without hatching taking place. This difficulty of getting the earliest stage from eggs renders the identification of the plankton specimens a very difficult task. The only method of overcoming this difficulty that seemed feasible was to keep post-larval specimens of each species in separate vessels filled with sea-water (the water was renewed twice or thrice a day) for as long a time as they would continue to live, and thus try to get at least some of the very late post-larval stages.

It has already been observed that on some days in a single haul there would be numerous specimens belonging to several stages. It could not, of course, be definitely ascertained in all cases which were the earlier and which the later stages by merely examining them. In all such cases where there was some doubt about the successive stages, they were kept separately in sea-water and allowed to moult and then the plankton specimens were compared with them. This was easy enough to do as invariably the moulting was accomplished in the course of a day or two. In this way complete series of larvae of a number of species were collected, four of which, viz., *Acetes sp.*, *Callianassa sp.*, a form belonging probably to *Upogebinae* and *Hippa asiatica* are described below.

Family SERGESTIDAE.

Sub-family SERGESTINAE.

Genus Acetes erythraeus, Nobili.

A complete account of the larval development of *Acetes* has not been given by any one till now, though some stages were observed and described by W. K. Brooks so far back as

1882. Four stages are mentioned by Brooks in his paper, of which the earliest stage is the last protozoea. The three others are later stages, and he obtained them by keeping a single specimen of the earliest stage in sea-water, though his figure of the last stage was drawn from another identical specimen captured at the surface. Since he had only a single specimen at his disposal his study of these later stages could not be extended to the mouth parts, as that would have involved dissection, and hence his descriptions of these stages are necessarily incomplete.

There can no more be any doubt regarding the identity of the two larvae figured by Fritz Müller in his "Facts and Arguments for Darwin." Brooks has already suggested the probability of their being the larvae of *Acetes* in his paper referred to above, and a comparison with the larvae described below proves that Brooks' suggestion is true. The one represented in Müller's fig. 32 corresponds with stage II of the present paper. The other (fig. 33) which is considered by Brooks as "extremely like, if not identical with, the one shown in fig. 90 " (of Brooks) shows exactly the same stage in the development of the abdominal limbs as stage VI of this paper.

The development of *Acetes sp.* from the earliest free-swimming larval stage up to one in which the animal has acquired the adult characters in all essential respects, will now be described. There are eight stages. The third of these is the last protozoea stage and is remarkably similar to the earliest stage of Brooks (pl. ix, figs. 78, 79 and pl. x, fig. 77) which also was the last protozoea as it directly metamorphosed into the mysis stage. Presuming that the three later stages described by Brooks succeed each other without any intervening unnoticed stages the American species is in possession of the full number of appendages after the third moult after the last protozoea stage (pl. xi, fig. 90). If the last stage of the Madras form is equivalent to the last stage of the American form, which is very likely, since both possess for the first time the full number of pleopods, the development of the former has several more stages than that of the latter. This extremely slow and gradual development of the abdominal appendages of the Indian form is the most striking difference in the development of the two species.

From October to the end of March these larvae were never absent from the townet collections. The number varied considerably from day to day, being extremely numerous on some days while only a few occurred on the intervening days; but no regularity in this variation was noticed. Generally a number of stages including some of the later ones were present, especially on those days on which they were captured in large numbers. In March swarms of these larvae, mostly in the early stages, were noticed in the plankton on three or four occasions. In April and the following two months they were practically absent, but fully developed immature specimens were occasionally present in April and fully matured ones towards the end of May.

Stage I, pl. i, fig. 1.—Length from the front edge of the carapace to the posterior margin of the telson ·58–·59 mm.

The animal appears as a white dot when viewed with the naked eye. It swims very actively, the abdomen then being bent down at an angle to the other part of the body. In

the later protozoea stages this flexure of the abdomen when swimming is more pronounced. The carapace is large, the breadth being much more than the length. It is produced into paired anterior and lateral spines and a median spine at the posterior end. There is no rostrum in this stage. A long spine which projects far beyond the anterior edge of the carapace is borne by the labrum. The anterior spines are each branched into two, each branch having short lateral processes. The lateral and the median spines are also provided with such lateral processes.

There is a distinct nauplius eye in the centre of the anterior edge of the carapace. The stalked eyes are present only as thickenings on either side of the nauplius eye on the ventral side of the carapace.

Antennule—Is little more than two-thirds of the carapace in length and is distinctly segmented, there being altogether seven segments. The first five joints are short, the sixth is the longest, being twice as long as the five proximal segments, and the seventh half as long as the sixth. The fifth joint has a short slender seta at the distal inner margin. A much larger seta is borne at the middle of the inner margin of the sixth and a pair more at its distal end. The terminal joint is tipped with four setae of which one is considerably longer and stouter than the others.

Antenna.—There is a two-jointed protopodite. The exopodite has two segments of which the proximal is much longer than the distal and carries on its inner margin two pairs of setae, the first pair arising near the base and the other from the distal end. The distal segment is tipped with five setae of which the innermost is much smaller than the others. The endopodite consists of nine joints all of which except the basal and the third carry one seta each internally and the terminal joint five. The third joint is only a partial one as the suture between it and the fourth does not extend to the inner margin. The fourth and sixth joints have each a short seta at their distal outer margins.

Mandible, pl. i, fig. 2.—The cutting edge is provided with nine teeth of which the ventral-most one is the largest. The next is only a minute tubercle at the base of the third which is long, slender and pointed. The fourth is short, stout and blunt. The other five are all of more or less the same size.

First Maxilla, pl. i, fig. 3.—The protopodite which is faintly two-jointed is produced inwards into two masticatory lobes, the proximal of which is armed with five (of which one arises from the middle of the proximal margin) and the distal with four stout setae. There is a three-jointed endopodite, the first joint of which carries three and the second two setae at their distal inner margins. The third joint has four terminal setae. There is a short knob-like exopodite bearing four plumose setae.

Second Maxilla, pl. i, fig. 4.—The protopodite has four lobes on the inner side, the lowermost of which is the largest. It is armed with six or seven stout setae while each of the other three is armed with four. The endopodite is four jointed (the joints are not plain). The first joint has four and the next two have two setae each. The fourth has five terminal setae. The exopodite is short as in the first maxilla, but is bordered with

five plumose setae, one of which, springing from the extreme posterior end, is much longer than the others.

First Maxillipede, pl. i, fig. 5.—The protopodite is long and stout each joint of which has a few (three or four) prominences on the inside each of which carries two or three setae. The endopodite is four-jointed. The first joint has three setae (one of which is rudimentary) and the next two joints two each. The terminal joint is tipped with five setae. The exopodite carries six setae three of which are on the outside and the rest terminal.

Second Maxillipede, pl. i, fig. 6.—The protopodite is shorter and thinner and unlike the first maxillipede has no prominences on the inside. The coxopodite is armed with one and the basipodite with three setae. The endopodite is four-jointed each of the first three of which has two setae internally and the last five at the tip. Exopodite as in the previous case is unjointed, half as long as the endopodite and bordered with six setae arranged as in the previous case.

Third Maxillipede—Is a small unjointed rudiment carrying two short setae terminally.

Behind this the next four segments of the thorax are clearly differentiated; they are not covered by the carapace. None of them possess any appendage. The fifth is absent.

The abdomen is rather short, being a little more than one-third of the thorax in length and is unsegmented. The telson has two widely separated forks each armed with six setae of which the two springing from the extreme tip of the fork are the largest. The outermost and innermost are the shortest, the latter arising not from the edge, but from the ventral surface close to the edge. All the setae are provided laterally with fine long cilia.

As has been already said above, the larva appears to the naked eye as a white dot. But microscopical examination shows the posterior end of the telson tinged light red. The endopodites of the antennae are also coloured similarly in its proximal portion.

Stage II, pl. i, fig. 7.—Total length ·92 mm.

The carapace has now a rostrum which reaches to two-thirds of the sixth segment of the antennule. The anterior, lateral and posteromedian spines are also present, but their lateral processes have now disappeared, and are replaced by scattered minute denticles. The anterior spines are still forked. The labral spine is unchanged.

The stalked eyes are now well developed and have stout stalks and pigmented cornea. They are not, however, completely free from the carapace. The nauplius eye is also present.

Antennule—Has undergone little change. A pair of aesthetes has now developed on the outer margin just below the terminal setae.

Antenna—Shows no advance on the previous stage. The number of segments in the exo and endopodites and their armature remain the same as in the first stage.

Mandible, pl. i, fig. 8.—The number of teeth has increased to 12–13. The ventral tooth still remains the largest. The pointed tooth which is now fourth from the ventral

side shows very fine serrations along its dorsal side. Besides these a number of small tubercles are present on the inner side close to the base of the teeth.

First Maxilla.—Same as in the previous stage. The distal endite has got one or two more setae.

Second Maxilla.—No change worth mentioning from that of the previous stage.

First Maxillipede, pl. i, fig. 9, *and second Maxillipede*—Show hardly any change except an increase in size.

Third Maxillipede.—Still rudimentary and tipped with two setae.

The remaining four thoracic segments do not show any limb rudiments in this stage also. In the abdomen anteriorly 3–5 segments are now clearly differentiated.

The telson shows no change from that of the previous stage.

The colouration has become more intense and has extended to other parts also. The posterior edge of the telson contains two small branching red chromatophores, one at the base of each of the forks. The tips of the forks themselves are light yellow. There is a very small red chromatophore at the base of each of the lateral and posterior spines of the carapace. The endopodite of the antenna contains an elongated thread-like chromatophore of the same colour. On the ventral surface there is a larger red chromatophore on either side near the mouth.

Stage III, pl. i, fig. 10.—Length from base of rostrum to posterior edge of

telson ...	...	...	...	...	1·4 mm.
rostrum	...	...	...	...	·4 mm.

Colouration is the same as in the second stage.

As has been observed elsewhere, this stage corresponds to the first stage described by Brooks (figs. 77, pl. x and 78, 79, pl. ix) and the resemblance between the two is strikingly close. Though the larva has increased in size, in general appearance and colouration there is hardly any change. The carapace retains all the spines of the previous stage. The rostrum has elongated slightly. The anterior spines have lost one of their forks.

The stalked eyes are now completely free from the carapace and very mobile. The nauplius eye persists as a dark spot between the bases of the two eye-stalks.

Antennule—Now consists of only three segments, the five proximal ones having fused to form one. The number of setae remains the same, but one more pair of aesthetes have made their appearance.

Antenna.—The exopodite remains unchanged The endopodite may be nine or ten jointed. The first, second and fourth, if there are ten joints and the first and third if only nine do not carry setae internally. The fourth is only incompletely differentiated from the fifth.

Mandible, pl. i, fig. 11.—Those of the two sides are slightly different. There are now two-pointed teeth with close serration on their dorsal sides. The hairy pad spoken of by Brooks as occurring on the posterior surface of the mandible (fig. 80, pl. ix) is absent in this case.

First Maxilla, pl. i, fig. 12.—Not much different from that of the previous stages. The proximal endite has now six setae and the distal seven. Other parts remain unchanged.

Second Maxilla.—Same as in the second stage.

First Maxillipede.—The protopodite and endopodite show no appreciable change. The exopodite is still unjointed and a little more than half as long as the endopodite. It carries eight setae, four of which are on the outer margin, two on the top and the other two on the distal half of the inner margin.

Second Maxillipede.—The coxopodite is armed with two and basipodite with four setae on their inner margins. Endopodite as in the previous stage. Exopodite is quite similar to that of the first maxillipede and carries eight setae.

Third Maxillipede, pl. i, fig. 13—Has grown a little and is now biramous. Both the exo and endopodites are unjointed and the former carries terminally three setae.

Behind the third maxillipede there are rudiments of the next four thoracic appendages, all of which except the last are biramous. The fourth is also much smaller than the others.

Abdomen—Shows the full number of segments. All of them have short lateral spines. Rudiments of the first five pairs of pleopods can with difficulty be made out in the form of small knobs on the ventral surface of the segments. The rudiments of the uropods are much larger and biramous, reaching to, or a little beyond, the posterior edge of the telson.

The telson shows no change.

Stage IV, pl. ii, fig. 14.—Length 2·3 mm. This stage closely resembles stage III of Brooks and is the mysis stage (fig. 85, pl. x). The animal has undergone a thorough change in shape and appearance. Instead of the broad flat thorax there is now a slender laterally compressed one. The abdomen also is equally slender. The carapace has lost all its spinous outgrowths except the rostrum which is distinctly shorter than that of stage III. At its base a single small tooth and some hairs are present. A pair of suborbital spines which were not present in the previous stages have now appeared at the anterior angles of the carapace. The spine of the labrum has disappeared. The posterior end of the carapace is concave and the angles rounded.

The stalked eyes have grown and are now about half as long as the first joint of the antennular peduncle. The nauplius eye is present as a vestige.

Antennule, pl. ii, fig. 15.—A peduncle and two flagella are now clearly differentiated. The former has a small swelling at its base in which the statocyst comes to be lodged later on and is three-jointed. The basal joint is the largest being about 3½ times as long as the second which is slightly shorter than the third. Along the inner border there are 7–8 plumose setae, three on the first, two on the second and three on the third joint. The external flagellum is as long as the second and third joints of the peduncle

and is divided indistinctly into four joints. On the inside it carries two large aesthetes. The inner one is ⅔ the outer in length and very slender.

Antenna.—There is a two-jointed peduncle. The flagellum is long and slender and distinctly segmented into eleven or twelve joints. The scale is a narrow short process and is armed terminally with a small spine and 5–6 short plumose setae.

The mouth parts show a very remarkable degeneration and do not seem to be of functional importance in this stage. In this degeneration of the mouth parts during the moult from the protozoeal to the mysis stage it resembles *Petalidium* (Gurney, 1924).

Mandible, pl. ii, fig. 16.—The cutting edge is devoid of teeth. There is no palp.

First Maxilla, pl. ii, fig. 17.—Both the endites are present. But instead of the stout setae of the previous stages they are now armed with short teeth, the proximal with 5–6 and the distal with five, of which those of the proximal are much larger. The endopodite and exopodite have completely disappeared and thus this appendage has assumed more or less the adult condition.

Second Maxilla, pl. ii, fig. 18.—All the masticatory processes except one have disappeared and even this persisting one is either wholly devoid of armature or provided with a few vestigial minute setae. The exopodite has expanded to form the scaphognathite with three plumose setae at the anterior end and one at the posterior end.

First Maxillipede, pl. ii, fig. 19.—Except in its armature, this appendage has acquired its adult condition. The protopodite is large and two-jointed, the joints however being quite smooth along their inner border. The exopodite is very slender and about as long as the basal joint of the protopodite, but is unsegmented and without setae.

Second Maxillipede—Does not show degeneration as the anterior appendages. There is a two-jointed protopodite and an exopodite which is a little less than half the endopodite in length and armed with three plumose setae terminally. The endopodite is five-jointed.

Third Maxillipede—Shows little difference from the second except in the comparatively greater length of the endopodite which, however, is a peculiarity of the adult also.

Thoracic legs—Behind the third maxillipede the first four thoracic legs are developed, the last segment and its appendage being absent.

The first three are biramous, each having an exopodite armed terminally with four plumose setae and a five-jointed endopodite which is chelate. The endopodites, all of which are directed forwards, are of unequal lengths. The first is the shortest. The third is about twice the first in length and in the forwardly directed position reaches almost to the anterior edge of the carapace.

The fourth leg (pl. ii, fig. 20) is uniramous, having only a short exopodite tipped with four plumose setae. Gill rudiments are absent.

Abdomen.—All segments except the last have lateral spines. The last segment which is the longest has a large, sharp, dorsal spine arising from the posterior edge. The fourth

and fifth have also smaller ones in the same position. The first three pairs of pleopods are developed, the fourth and fifth being only knob-like rudiments. The pleopods are uniramous, each having a one-jointed protopodite and an exopodite.

Uropods—Are well-developed. Both the inner and outer lobes are long, rather narrow structures almost equal in length and breadth. The endopodites are bordered with long plumose setae (9–11 on each margin and two terminally). The inner margin of the exopodite has 12–13 plumose setae, but the outer has only five confined to its distal portion which is about one-third of the whole margin in length. A small sharp spine is present just anterior to the commencement of this ciliated part of the outer edge.

Telson.—The forks of the previous stage are closely approximated and directed backwards and are fused together except at the extreme posterior end. The long setae of the previous stage have shortened into sharp spines.

Stage V, first Mastigopus stage, pl. ii, fig. 21.—The animal has increased in size. In appearance it resembles the adult. The carapace possesses all the spines that were present in the previous stage and in addition a small tooth-like supra-orbital spine has appeared. The rostrum has shortened a little and there is still only one tooth behind it. In the abdomen also all the spines that were present in the previous stage persist.

The stalked eyes have now elongated, the stalks being long conical structures. The nauplius eye still persists as a dark spot.

Antennule.—The peduncle is more or less unchanged except in the number of setae it bears which in some has increased to ten, six on the proximal segment and two each on the other two. Some shorter setae are present on the outer side and along the sutures. The swelling at the base of the peduncle has become bigger and there is now a round statocyst in it. Both the flagella have grown in length. The inner is thinner, unjointed, about half as long as the outer and tipped with four setae. The outer is distinctly segmented. The first joint has two aesthetes as in the previous stage, and the second and third have each two terminal setae.

Antenna.—The flagellum has grown very much in length and consists of numerous joints, the most proximal three of which are much thicker than the others and together with the protopodite joints form the five-jointed stalk of the adult. The scale is still narrow and is bordered on the inside and tip with 8–10 plumose setae. The outer edge is devoid of setae and ends distally in a short, sharp spine.

Mandible, pl. ii, fig. 22.—The cutting edge has now two sharp teeth ventrally and three blunt tubercles at the dorsal end. There is no palp.

First Maxilla, pl. ii, fig. 23.—Both the endites are armed with several short, stout setae. The basal portion of the proximal endite is bare.

Second Maxilla, pl. ii, fig. 24.—The single endite has five or six long setae. The scaphognathite bears plumose setae only at the anterior and posterior ends.

First Maxillipede, pl. ii, fig. 25.—The proximal joint of the protopodite has six or seven setae on the distal part of its inner margin and the distal joint has several along the whole

length of the same margin. A minute rudimentary epipodite is present on the proximal joint. The exopodite is unsegmented and tipped with two short setae.

Second Maxillipede, pl. ii, fig. 26—Is bent backwards in the form of a V with its apex forwards. It is six-jointed, the basipodite having fused with the ischiopodite and of the six the dactylus is the shortest except the basal joint. There are stout setae along the whole length of the appendage.

Third Maxillipede.—Is pediform. It is much longer than the first leg and is seven-jointed. All joints are setose. In the second and third maxillipedes as well as in the following legs there are very short vestiges of exopodites, which are, however, unarmed.

Walking legs.—There are only three legs, the uniramous fourth leg having disappeared. The only difference between them and those of the previous stage is the increase in length and the presence of setae on all the joints. The tips of the fingers of the chelae have small clusters of setae. No distinct suture is visible between the ischium and merus in any leg, the only indication being a slight swelling.

Three small gill rudiments belonging to the segments of the third maxillipede and the first two legs are noticeable.

Abdomen.—Only the first three pairs of pleopods are present. They have grown longer and consist of long peduncles and narrow exopodites. The latter are bordered with long plumose setae, the first having fourteen and the second and third twelve. Rudiments of fourth and fifth pairs remain unchanged.

Uropods.—Show no change worth mention.

Telson.—On the posterior edge there are now only four spines of which the inner pair are much larger.

Colouration.—The ocular peduncles have each a branching red chromatophore at about their middle. The long flagellum of the antenna has got broad red bands along its whole length. On the ventral side of the abdomen between the bases of the pleopods there are small branching red chromatophores and somewhat larger ones in the peduncles of the uropods. The red patch near the mouth present in the previous stages is also present. Besides these the ventral side of the thorax between the legs may also be coloured.

Stage VI, pl. ii, fig. 27.—Length 3 mm. Externally the thorax and abdomen remain unchanged. The eyes have grown slightly. Vestige of nauplius eye present.

Antennule.—Has grown considerably and equals the carapace in length or is longer. The inner and outer margins have ten or eleven and five or six plumose setae respectively. The swelling at the base of the peduncle which lodges the statocyst has two short plumose setae on its top. There are now about twelve joints in the external flagellum. Its base is thickened as in the adult and bears three or four aesthetes. Inner flagellum has not undergone much change.

Antenna.—The flagellum is more than twice the whole body in length. The plumose setae on the scale have now increased to thirteen.

The mandibles and first maxillae are not changed and persist in the following stages little altered except in size. The palp of the former appears only very late, being first noticed in a specimen measuring 5·75 mm.

Second Maxilla, pl. ii, fig. 28.—The outer border of the scale is not completely fringed with setae. About twenty are present at this stage.

First Maxillipede, pl. ii, fig. 29.—The rudimentary epipodite has grown into an oval flat structure. The maxillipedes and walking legs are longer and armed with more setae. The vestiges of exopodites have completely disappeared.

There are four gill rudiments, which are better developed than in the preceding stage.

Pleopods.—The first two are still uniramous but the third has a very small bud-like endopodite (pl. ii, fig. 30). The exopodites of the first pair are bordered with sixteen and of the second and third with fourteen plumose setae. The rudiments of the fourth pair are now as long as the peduncle of the third pleopod. Each has a short peduncle, an exopodite and a small papilliform endopodite. They don't carry setae. The rudiments of the fifth pair have not grown much. The telson and uropods present no difference.

Stage VII, pl. iii, fig. 31.—Total length 3.5 mm.

The externals of the animals do not show any fresh characters worth notice. The stalked eyes have grown in length. The vestige of nauplius eye persists.

Antennule, pl. iii, fig. 32.—The plumose setae on the inner and outer margins are 11–13 and 5–8 respectively. Arising from the outer distal angle of the basal swelling there is a sharp spine. The outer flagellum is twice as long as the peduncle and consists of 16–17 joints. Its thickened basal portion carries five aesthetes. The inner flagellum is three jointed and only a little longer than it was in the previous stage.

Antenna.—The scale now reaches up to the tip of the second joint of the antennular peduncle. It has broadened a little and carries along the inner border and tip 15–17 plumose setae. The flagellum has elongated still more and is about 12 mm. long.

Second Maxilla, pl. iii, fig. 33.—The endite has now eight setae as its tip. Besides these on its proximal border at about the middle there is a small seta. Even now a portion of the outer border of the scale is devoid of setae, there being 20 to 22 setae in the other portions. At the base of the endite, on its outer margin, there is a very small protuberance which seems to be the rudiment of the future palp.

First Maxillipede.—No change.

Second Maxillipede, pl. iii, fig. 34.—On the coxopodite there is a very small knob-like outgrowth which is the rudiment of the epipodite present in the adult appendage. The propodite is provided with numerous stiff setae set close together along the whole length of its inner border.

Third Maxillipede and the walking legs—Are not much changed. Still there are only four gills.

Pleopods.—The first two pairs are still uniramous and their exopodites are fringed along the margins with 16–18 plumose setae. The exopodites of the third and fourth pairs have 14–16 and 10–12 plumose setae respectively along their margins. The inner lobes of these have grown a little, but are unarmed. The fifth pair is still uniramous rudiments. Telson and uropods—in the same condition as in previous stage.

Stage VIII.—Total length 4 mm.

The shape and appearance of the thorax and abdomen are as they were and there are the same spines as were present in the previous stages. The rostral crest has still only one tooth. The lateral spines of the abdominal segments are reduced a little.

The stalked eyes have grown a little more. The vestigial nauplius eye is still present.

Antennule.—The comparative lengths of the joints of the peduncle remain unaltered. The inner border carries fourteen and the outer ten plumose setae. The spine on the upper outer angle of the swelling at the base has grown in size. The thickened basal portion of the external flagellum carries six aesthetes. Inner flagellum remains unchanged.

Antenna.—The only changes worth noticing are the increase in length of the flagellum and the increase of the plumose setae on the scale to 21.

Second Maxilla.—The endite is tipped with nine or ten setae. The rudimentary seta on its proximal side is also present. The hind end of the outer border of the scale is still devoid of setae. (About 32 plumose setae are present on the other parts.) The palp has grown into a conical papilliform process.

First Maxillipede.—Same as in previous stage.

Second Maxillipede.—The rudiment of the epipodite has grown into an oval protuberance. The third maxillipede and the perieopods present hardly any difference from the foregoing stage.

A very small gill rudiment has appeared behind the others so that now the full number of gills of the adult is present.

Pleopods.—All the five pairs are now fully developed. The first pair is still uniramous and has not altered. The second has a small papilliform endopodite. The endopodite of the third is now two-thirds the exopodite in length and is bordered with 8–12 plumose setae, the exopodite having the same number of setae as in the last stage. In the fourth also both exopodite and endopodite are setose, the former having 14–16 and the latter 8–12 plumose setae. The fifth pleopod has only a short unarmed endopodite, the exopodite of which is bordered with 10–14 setae. The pleopods gradually decrease in length from before backwards.

Telson.—The telson has elongated slightly.

Uropods.—The size has increased a good deal and the setae on the borders of the lobes also have increased in number.

It will be seen from the above account that the development of *Acetes* follows in general the course of development of *Sergestes*. In both there are three protozoea stages. In the first stage there is no rostrum, the stalked eyes are not present, the carapace bears anterior and posterior spinous processes and a posterior median process. "The first two pairs of maxillipedes are present as biramous swimming organs and the third is a small uniramous rod" (Gurney).

In the second stage the eyes are stalked and a long rostrum has appeared.

In the third stage the thorax bears rudimentary legs and the rudiments of the uropods have appeared.

Notwithstanding these similarities, there are striking differences between the two forms, especially in the second and third stages. The rostrum in the second stage of the *Sergestes* protozoea is large with a number of lateral and ventral spines, whereas in *Acetes* it is a simple spinous process with scattered minute denticles on its surface. The anterior processes of the carapace are lost in *Sergestes*, but they are only reduced in *Acetes* and the stalked eyes of the latter, unlike those of *Sergestes*, are not completly free from the carapace. In the third stage the conspicuous, branched, supra-orbital processes of the carapace of *Sergestes* are absent in *Acetes* (but the reduced anterior process of the last stage persist in a still more reduced condition in this stage) and it does not have the fifth pair of thoracic appendages, even the somite itself being absent.

The last protozoea is succeeded by two mysis stages in *Sergestes* while there is only one in *Acetes*. The great change of form, the reduction and disappearance of the spines of the carapace, the presence of biramous thoracic appendages and pleopod rudiments are some of the characters in which the two forms resemble each other. The differences, however, claim more attention than the similarities. The most remarkable difference between *Acetes* and *Sergestes* in this stage is the curious degeneration of the mouth parts of the former into quite functionless structures, those of the latter persisting in the condition in which they were in the last protozoea stage with little alteration. In this respect *Acetes* resembles *Petalidium*, the metamorphosis of which is given by Gurney (1924) and his remarks on this stage of *Petalidium* are applicable to *Acetes* also :—" In the development of all the pereiopods with natatory exopodites it agrees with the acanthosoma stage, but in other respects it may more properly be compared with the mastigopus. The acanthosoma stage has, in fact, been dropped out of the series, and has been replaced by a larva of unique character intermediate between the acanthosoma and the mastigopus." Another important difference between *Sergestes* and *Acetes* concerns the thoracic appendages. All the five pairs are present and functional in *Sergestes*, while in *Acetes* the fourth pair is uniramous, the fifth is absent and the first three pairs which are well developed do not seem to be functional.

The mastigopus stage persists through a number of moults in both forms during which the fourth pereiopod in *Acetes* and fourth and fifth in *Sergestes* are lost, the mouth parts take on the adult form and the pleopods become functional.

The only other genus of the sub-family whose development is known to us, though not fully, is *Petalidium*, between which and *Acetes* there is much less resemblance in the

earlier stages than between the latter and *Sergestes*. In *Petalidium* also there are three protozoea stages. In general appearance, and especially in the possession of well developed stalked eyes and rostrum, the absence of the anterior spinous processes and the shape and armature of the telson, the first stage of *Petalidium* is entirely different from that of *Acetes*. Most of these differences continue to exist in the succeeding two stages also so that a detailed comparison of these stages of the two forms is unnecessary.

In the mysis stage though there are numerous smaller differences, the almost identical kind of degeneration undergone by the mouth parts in both is a very important point of resemblance and so far as this is concerned, they differ from both *Sergestes* and *Lucifer*, the two other genera of the Sergestidae of which we know the development.

Only the earliest mastigopus of *Petalidium* is available for comparison, but that also like the mysis stage resembles the first mastigopus of *Acetes* in several important respects. Though they differ in shape, the carapace in both has (1) a rostrum with only a single tooth behind it, (2) a pair of supra-orbital spines and (3) a pair of sub-orbital spines (the hepatic spines present in *Petalidium* are absent in *Acetes*). Abdominal segments 4, 5 and 6 have short dorso-median spines at their posterior edge (these spines were present in the last stage also). The mouth parts have become functional and the maxillipedes and pereiopods have lost their expodites and acquired more or less their adult forms. The third legs in both are much longer than the others and the fourth and fifth legs have disappeared in both. The pleopods are still uniramous, but are clothed with setae and functional. The shape, the nature of antennule, antennae and some of the mouth-parts and the presence of all five pairs of pleopods in the abdomen are some of the important points of variation between the two. It would thus appear that the wide divergence of the early stages (protozoea) of the two forms becomes considerably less in the mysis and mastigopus stages.

A comparison of *Acetes* and *Lucifer* need not be attempted here as it has already been made by Brooks. The absence of the fifth thoracic somite and its appendages in both from a very early stage seems to be the most important point of resemblance. Similarly the disappearance of the fourth and fifth pairs of legs during the moult from the mysis to the mastigopus stage, even in genera like *Sergestes* and *Petalidium* in which the fourth or both fourth and fifth legs are present in the adult, is also significant.

The only Indian species[1] of *Acetes* that has been recorded is *A. indicus* Milne-Edwards from the mouth of the Ganges. It was first figured and described by Milne-Edwards in 1830 in the Annales des Sciences Naturalles. Though he gives good figures of the entire animal and some appendages, his account is so meagre as to be of little use for purposes of identification. Later in 1852 Sir Walter Elliot obtained numerous specimens from the inside of a large fish, and a figure of one of these specimens without any description is given by Spence Bate in the Challenger Reports (fig. 1, pl. XXXV—Crustacea Macrura). J. R. Henderson also (A contribution to Indian Carcinology, 1893) mentions the

[1] Kemp (*Rec. Ind. Mus.* XIII, pp. 43–58, text figs.) describes three Indian species. This paper is omitted from Hansen's bibliography in his *Siboga* Expedition report and came to my notice after the present paper was in proof. The species described above is evidently *A. erythraeus*, Nobili.

occurrence of the same species in the Gulf of Martaban in Burma and in Singapore. But he has given neither figures nor a description of his specimens. H. J. Hansen seems to have been unaware of its presence in these latter localities and hence he says in his remarks on *A. indicus* that it has never been re-discovered and that it ought to be looked for only in the Ganges. (Sergestidae of the Siboga expedition.)

The only character of specific importance which can be made out in Edward's figures is, according to Hansen, the relative length of the ciliated portion of the outer margin of the exopod of the uropods which is one-third of the whole margin, the only other species known so far which shares this character being *A. americanus*, Ortmann. Bate's figure does not show the uropods clearly. Edwards shows a tooth on the outer margin of the same exopod close to the anterior end of the ciliated portion, which, however, is absent on the other side. Both in his and in Bate's figures the supra-orbital spine is not shown, but in the latter, there is a distinct hepatic spine. There is also some difference between the antennular flagella though apparently, both figures represent females (the rudiments of the fifth legs called genital coxae by Hansen being absent). Numerous adult specimens of the present form were collected with the tow-net from May to November. A brief account of the important characters of these is given below, so that a comparison with other recorded Asiatic species can be made, with none of which, however, does it agree closely.

The rostral crest in both sexes bears two teeth, the posterior of which is larger than the other. Supra-orbital and hepatic spines are also well developed in both sexes.

Male.—The transverse diameter of the eye is much more than half the distal joint of the peduncle with eye. The second and third joints of the antennular peduncle are somewhat thicker and longer than those of the female. Third joint is about 1¾ times as long as the inner margin of second joint. Thickened part of the upper flagellum is half as long again as the inner margin of second joint of antennular peduncle. Lower flagellum is longer than third joint, but not quite so long as second and third together, and consists of 15–16 joints. The "main branch" of the "clasping organ" of lower flagellum (pl. iii, fig. 35) is slightly curved proximally. At the base of its first joint and arranged along the posterior edge of an excavation on its outer surface there are three short, curved teeth. Each of the three next joints and the sixth has one tooth on the lower side. The fifth joint has three much larger teeth. (This number is, however, variable. Though in the majority the number was three, specimens were examined in which the number was two or four.) The shaft of the clasping organ is three-jointed and from the lower side of the distal end of the third joint, there arises a long, stout, very much curved spine, the tip of which reaches the teeth of the fifth joint. The spine bears on its dorsal surface a number of minute denticles which are particularly dense towards the tip. A small tooth is present on the short process from which the ventral spine originates, in a row with the three teeth of the first joint of the main branch. The antennal scale reaches to two-fifths of the third joint of the antennular peduncle. The genital coxae as in A. vulgaris are triangular and distally produced into narrow, slightly curved, subacute processes. The coxopodite of third leg may or may not have a rudimentary

tooth on its distal inner margin, the basipodite being without one. The exopodite of the uropods (pl. iii, fig. 40) is slightly more than 4½ times as long as broad and the ciliated part of its outer margin is two-fifths of the whole and just in front of it there is a short spine.

Petasma, pl. iii, fig. 36.—Pars externa is about twice as long as broad. Anteriorly a little less than half of the outer margin is convex. Pars astringens has a long inner margin with hooks, which is about twice the processus ventralis in length. The capitulum and processus ventralis together form two-thirds of the pars media. Processus ventralis has a sinuate outer margin and is half as long as the capitulum. The distal narrow portion of the latter is shorter than the broad proximal part. At the outer margin of the capitulum (pl. iii, fig. 37), there is a very large hook proximally and a little beyond it there is a much smaller one. Along the middle there is a longitudinal row of small hooks, several of which are present at the tip also.

The largest specimen measured 26 mm.

Female, pl. iii, fig. 38.—Second and third joints of the antennular peduncle are shorter than those of the male and are together as long as the first joint. Third joint is a little less than twice the second in length. Thickened part of upper flagellum is equal to the third joint of the peduncle in length. Lower flagellum has nineteen joints and is as long as the two distal segments of the peduncle. Antennal scale reaches to the middle of third joint of antennular peduncle. Coxae of third pair of legs with a well-developed tooth at the distal inner margin, which is concave due to a protuberance of its proximal part inwards.

Genital area, pl. iii, fig. 39.—The anterior part of the sternal plate of the seventh segment has two triangular processes with obtuse extremities situated between the coxal protuberances. Behind them there is a procurved furrow separating the seventh and eighth segments.

Largest specimen measured 30 mm.

It will be evident from the above account that this form resembles *A. vulgaris* and *A. sp.* described by Hansen with regard to the diameter of eyes, the comparative length of the joints of the antennular peduncle, length of the antennal scale, etc. At the same time there are important differences which make it impossible to refer this to either of these species. The differences between this and *A. vulgaris* are (1) the greater length of the thickened part of upper flagellum, (2) presence of spines on the first joint of the main branch of the clasping organ, (3) presence of a tooth on the outer margin of the exopod of the uropods and (4) the totally different petasma of the male. With regard to the genital area of the female if the large triangular processes of this form can be regarded as corresponding to the small round protuberances of *A. vulgaris* the difference is only slight. From *A. sp.* of Hansen it differs in (1) item (2) mentioned above, (2) absence of spine on seventh joint of main branch of clasping organ, (3) presence of rudimentary tooth on the coxa of third leg in male, (4) the greater length of the terminal processes of genital coxae and (5) the genital area of the female. However, the petasma is almost identical in both forms. It is impossible, in the light of the above mentioned facts, to

resist the conclusion that this is a different species from both *A. vulgaris* and *A. sp.* At the same time it is closely related to them and together with them forms a distinct group which differs from all other recorded Asiatic forms, except possibly *A. sibogae* in some important characters.

Since our knowledge of *A. indicus* is extremely imperfect no opinion can be hazarded about the relationships of the Madras form to that species. The only reliable specific character of *A. indicus* is the length of the ciliated part of the outer margin of the exopod of the uropods and it is much longer in the present form. Also *A. indicus* does not seem to possess a supra-orbital spine. It should be mentioned, however, that the presence of a tooth on the outer margin of the outer lobe of the tail fan is a point of resemblance between the two. Moreover the comparative lengths of the joints of the antennular peduncle and thickened part of upper flagellum in Bate's figure referred to above are the same as in this form. These resemblances and the fact that this species has been recorded from stations so far off from the place of its discovery as the Gulf of Martaban (Burma) and Singapore, make a decision (only on the strength of the differences pointed out) in favour of the distinctness of the present form from *A. indicus* difficult. The question can be decided only after a study of the type specimens of any of the authors referred to above.

Family CALLIANASSIDAE.

Sub-family CALLIANASSINAE.

Genus Callianassa.

Larvae of this interesting Callianassid were obtained in December and January. Their comparatively large size and their habit of keeping to the surface when the tow-net collection is kept in shallow glass vessels make them easy of recognition. They do not occur in large numbers, not more than a dozen having been captured on any day. In December and the first half of January only the two early stages were present in the plankton. Towards the end of the latter month on two or three occasions a few specimens of the first post-larval stage were also obtained.

Stage I, pl. iv, fig. 1.—Total length from tip of rostrum to posterior end of telson 6·5 mm.

The rostrum is as long as the antennules, broad and dorsoventrally flattened. At the anterior end it narrows considerably and ends in a point. A few minute teeth are present on the edges at the anterior end. The antero-lateral edge of the carapace is serrated, there being about 10 small teeth, and there is a distinct sub-orbital spine at the anterior end. The posterior end of the carapace is deeply concave and is rounded at the corners. Unlike the larvae of other species of *Callianassa* there is no large dorsal spine on the second abdominal segment. The third, fourth and fifth have small dorsal spines at their posterior ends, of which the last is larger than the others and is curved down.

The eyes are carried on short thick peduncles and are pigmented.

Antennule, pl. iv, fig. 2.—There is a peduncle and two short flagella. The former does not show segmentation and has neither spines nor setae. The internal flagellum is half as long as the external and carries one long, stout plumose seta terminally. The outer shows three faintly marked joints, the first two of which have each two large aesthetes. The third has three which are narrower than those of the lower segments and also three ordinary setae.

Antenna, pl. iv, fig. 3.—The peduncle is two-joined. Basipodite is produced into a short spine above the base of the flagellum. The latter is about three-fourths as long as the scale and does not show clear indications of segmentation. Terminally it is armed with two plumose setae. The scale ends distally in a short, stout spine and is fringed along the inner edge and tip with seventeen plumose setae.

Mandible, pl. iv, fig. 4—Has a well-developed unjointed palp. The cutting edge is smooth except for the presence of a minute tooth.

First Maxilla, pl. iv, fig. 5.—The proximal endite is armed with five teeth, one of which is very small. The distal endite has one very small tooth as its lower end and two or three minute tubercles above. There is a well-developed unjointed palp.

Second Maxilla, pl. iv, fig. 6.—There are four endites, the two middle ones of which are smaller than the others. The basal and the next are unarmed; the other two are armed each with a small seta. The endopodite is unjointed and tipped with two setae. The scale has a fringe of 24 plumose setae.

First Maxillipede, pl. iv, fig. 7.—The coxopodite bears only one seta on its inner margin. The basipodite has eight which are, however, shorter than that of the former. The endopodite has three terminal setae of which one is rudimentary. The exopodite is twice as long as the endopodite, unjointed and is tipped with four plumose setae. There is a flat epipodite.

Second Maxillipede, pl. iv, fig. 8.—The endopodite is four-jointed. A slight constriction towards the base of the proximal joint may indicate that it is formed by the fusion of the first two joints. Exopodite has four terminal plumose setae.

Third Maxillipede.—Similar to second. The exopodite has five plumose setae.

Behind the third maxillipede there is no free appendage in the thorax though the full number of appendages appear as prominent swellings beneath the cuticle of the ventral side.

Abdomen—Consists of six segments besides the telson. The first segment is the shortest, being only half as long as the second and the sixth is the longest. The first two segments are without appendages. The three following ones possess well-developed biramous pleopods which are not clothed with setae (pl. iv, fig. 9). There are no uropods.

The telson (pl. iv, fig. 10) is a broadly triangular structure with a slight notch in the middle of its posterior edge, where there is a large median spine. This does not show any articulation with the telson, but seems to be a continuation of the edge. On either

side of this there are 17–19 spines of which the second from the side is reduced and hair-like. The spines gradually increase in size from the centre to the sides. All spines except the median and the two outermost ones are ciliated.

The body is perfectly transparent except for a short streak of pink colour along the lateral margin of the carapace and a patch of similar pigment on the ventral side just behind the mouth.

Stage II.—Total length 7·5 mm.

In shape and general appearance the larva has undergone no modification. The most important difference between this and the previous stage is the presence of the full number of free thoracic appendages in this. The lateral margins of the rostrum are toothed along their whole length. The carapace remains as it was in the previous stage. In the abdomen the spine on the third somite is better developed. In addition to those already existing a small dorsal spine and a much larger ventral one are present at the posterior end of the sixth somite. An extremely small lateral spine may also be present in the same somite.

Antennule, pl. iv, fig. 11.—The peduncle is now clearly three-jointed, the basal joint being the longest. The first and second joints carry four and five short plumose setae respectively, on their outer margin. On the inner margin of the second joint there is one long plumose seta and five similar ones are present on the third. The inner flagellum has elongated and equals the outer in length which is as long as the distal joint of the peduncle. The external flagellum has got the same number of aesthetes as in the last stage and the internal is tipped with two unequal setae, the larger of which is plumose.

Antenna, pl. iv, fig. 12.—The basipodite now carries two spines, one above the base of the flagellum and the other above that of the scale. The scale is bordered on the inside and tip with 18–20 plumose setae. The flagellum is as long as the scale and is tipped with two short setae. Faint indications of segmentation are seen beneath its cuticle.

Mandible.—The cutting edge shows two well-defined, round, smooth lobes, but is devoid of teeth.

First Maxilla.—The palp has a small terminal seta. The armature of the endites shows no difference from that of the previous stage except the addition of a tooth on the distal endite.

Second Maxilla—Has not altered appreciably. The fringe of plumose setae on the scale has increased in number to about thirty.

First Maxillipede.—The endopodite and exopodite are armed terminally with four and five setae, respectively. The other parts remain unchanged.

Second Maxillipede.—A small epipodial rudiment has appeared on the coxopodite.

Third Maxillipede—Remains unaltered. Behind the maxillipedes all the other thoracic appendages are now free and functional.

The legs, except the last, have well-developed exopodites with five terminal plumose setae. The last does not show any trace of an exopodite. The endopodites are all five-jointed. The first (pl. iv, fig. 13) and second (pl. iv, fig. 14) terminate in well-developed chelae, the others in long, pointed, claw-like processes of the dactylopodites (pl. iv, fig. 15). The propodite of the third is expanded and has more or less acquired the characteristic shape it has in the adult. The same segment in the last leg sends a short process from its tip below the base of the dactylopodite so that the tip of this leg already shows its subchelate nature.

Gills, pl. iv, fig. 16.—Rudiments of the full number of the adult are present. The maxillipede and the following four legs have each two gill-rudiments. The last leg has none and the single rudiment of the second maxillipede is hardly perceptible.

Abdomen—Shows a slight elongation. The first and second somites are still without appendages. The uropods are not yet fully developed, but appear in the form of thickenings along the sides of the anterior part of the telson.

Telson.—So far as shape is concerned there is absolutely no change. Only sixteen spines are now present on either side of the large median spine. In most of the interspaces between the spines the edge of the telson bears two or three small setiform teeth.

There is no change in colouration.

Stage III, pl. iv, fig. 17.—Total length of the animal 6 mm.

Like the previous stages this is also perfectly transparent and colourless except on the ventral side near the mouth where there is a patch of red colour. There is a short broad rostrum with blunt tip which is bent down between the eyes. The *linea thalassinica* could not be clearly made out. The hind end of the carapace is deeply concave and the postero-lateral portions are rounded. The lateral and posterior margins bear a few short setae. The eyes are short and thick and the cornea is well-pigmented. The proximal portions of the stalks are flattened on the inside and are closely pressed together.

Antennule, pl. v, fig. 18.—The peduncle is three-jointed and bear about eleven setae on the two distal segments. The flagella are now distinctly segmented, both having five segments. The inner is slightly longer than the outer which is as long as the third joint of the peduncle. Both are armed with setae and the outer has four aesthetes in addition.

Antenna, pl. v, fig. 19.—The two spine-like processes of the basipodite have now disappeared. The scale persists in the form of a clubshaped structure as long as the peduncle and armed with two or three setae. The flagellum has increased greatly in length and has got 15–17 joints, most of the joints being armed with short setae.

Mandible, pl. v, fig. 20.—The masticatory portion is deeply divided into two lobes, both of which carry long, narrow, pointed teeth. The palp is unjointed and bears terminally a rudimentary seta.

First Maxilla, pl. v, fig. 21.—The palp is three-jointed and is armed with six very short setae at the distal end. The proximal endite is very small and devoid of setae. The distal one is broad and has four small blunt prominences.

Second Maxilla, pl. v, fig. 22.—All the endites are armed with numerous setae. The scaphognathite is bordered with 37 plumose setae. The endopodite carries five setae of which three are terminal.

First Maxillipede, pl. v, fig. 23.—Both the coxo and basi-podites have well-developed masticatory lobes armed with several setae, a few of which, springing from the middle of the proximal lobe, are plumose. The extreme basal part of the proximal lobe is bare. The endopodite is small, being not even half as long as the exopodite and is unarmed. The latter is broad and unjointed and carries ten plumose setae which are distributed on the tip and the distal half of the outer margin. Besides these a rudimentary one is present on the inner margin close to the tip. The epipodite has increased considerably in size.

Second Maxillipede, pl. v, fig. 24.—The endopodite is rather broad, curved inwards and four-jointed. The basal joint is the largest and as in the previous stages shows a slight constriction near the base thus indicating that it is formed by the fusion of two joints. There is a rudimentary epipodite in the form of a round protuberance. The exopodite is a vestige, about as long as the first two segments of the endopodite and tipped with two short setae. All joints of the endopodite except the second bear setae.

Third Maxillipede, pl. v, fig. 25—Is rather broad due to the flattening of the first four joints, among which the propodus is a little broader than the others. The dactylus as in the preceding limb is very small. All joints are armed with setae, those along the inner margin being larger and more closely arranged. The exopodite is similar to that of the second maxillipede.

Pereiopods.—The first and second are chelate.

The chelae are equal. In the first (pl. v, fig. 26) the ischiopodite is rather slender. The carpus and propodus, especially the latter, are large and massive. The fingers are almost equal in size and about ⅔ as long as the rest of the propodus. The distal portion of the inner margin of the carpus and the entire inner margin of the propodus as well as the outer borders of the fingers are armed with long setae. The cutting edge of the fixed finger shows three small triangular cusps while that of the other is smooth.

In the second leg (pl. v, fig. 27) all the segments are rather stout. The fingers are equal in size. The inner edge of the fixed finger bears three prominent teeth rudiments, while the dactylus has a smooth cutting edge. The inner margin of the merus and both margins of the carpus and propodus are armed with setae, those on the inner being longer and stouter. The fingers are also provided with setae along the outer edge and a few are present on the inner edge also.

Third leg, pl. v, fig. 28.—The ischium, merus and carpus are rather slender, but the propodus is greatly expanded at the base so as to form a triangular lobe. The dactylus is small and triangular. Both the propodus and dactylus are thickly set with setae, those along the hinder edge of the propodus being much larger than the others.

The fourth (pl. v, fig. 29) and fifth legs are very slender when compared with the preceding. The last two joints of both are provided with close-set setae.

The fifth leg (pl. v, fig. 30) is distinctly subchelate and its propodite is armed with a cluster of setae arising just behind its distal end.

Each of the first four pereiopods carries a small spineless process on the outside of the basipodite which is the vestige of the exopodite.

Abdomen.—The sixth segment is longer than those in front. The pleural margins of the first five somites have a few hairs but those of the sixth segment are fringed with stout plumose setae throughout their length all of which are curved backwards. The first two somites are still devoid of appendages, the succeeding four segments having large pleopods.

Pleopods, pl. v, fig. 31.—Each pleopod has a short thick peduncle and two broad flattened lobes, the inner of which is shorter than the outer. Both the lobes are bordered with long plumose setae except on the proximal half of the inner margin of the outer lobe. The inner margin of the endopodite has a small appendix interna carrying five hooks.

Uropods, pl. v, fig. 32.—These are large. The outer lobes are much broader than the inner, their outer margins being almost twice as broad as those of the inner. Their anterior, outer and distal halves of the posterior margins are set with plumose setae, some of which are considerably shorter than the others. The inner lobe is shorter than the outer and bears setae only on its posterior border. A few plumose setae are present on the peduncle.

Telson—Shows slight variations in length in different specimens. It may be as long as or slightly longer or shorter than the inner lobe of the uropods. It is not rectangular as in other species of Callianassa, the posterior end being about a third as broad again as the anterior end. The posterior edge has still got a shallow central notch in which the vestige of the median spine persists. On either side of this there are short plumose setae and a few smooth, slender setae arising in front of the edge. Of these one at each angle is very long. On the dorsal side arising from a prominence there are four setae two of which are shorter than the other two.

The larvae of this species are remarkably different from those of the other species of *Callianassa* so far studied. Gurney has drawn up a list of characters of the larval stages of this species which "may be regarded as valid for the whole genus."

They are—

1. Rostrum broad, flat, toothed along edges.
2. Eyes, oval.
3. Pleon somite two with a very large dorsal spine which is hollowed below.
4. Pleon somites 3–5 with median carina and small spines.
5. Telson with median spine, broad and triangular in stage I and elongated, rectangular in last stages with a formula 8+1+8.
6. Fifth pereiopod without exopodite.
7. Pleopods absent from somites 1 and 2.

So far as the first two and the last two characters are concerned the present form is in perfect agreement with the other species. But with respect to the other characters there are important differences. There is no dorsal spine on the second abdominal somite and although somites 3–5 have small dorsal spines, there is no carina on any one of them. The telson is broad and triangular in the two stages preceding the post larval and the number of spines on either side of the median one is more than twice the usual number in other species of *Callianassa.* It is not rectangular, even in the first post larval stage Besides these the oral appendages (mandible, first and second maxillae and first maxillipede) also show a vast amount of difference due apparently to a partial degeneration of the masticatory lobes. The very late appearance of the uropods is another important variation from the other species, in which they are developed in as early a stage as the third, though the pleopods are then undeveloped and only two pairs of biramous legs are present.

The abbreviated larval development of this species, though apparently unique so far as Callianassidae is concerned, resembles the development of *Axius* and some other species of the family Axiidae in which, as Gurney remarks, it is probably a general rule, the eggs being of unusually large size. It is impossible to say anything at present about the nature of the eggs of this form, since I have not yet succeeded in obtaining mature females with eggs. So far as larvae are concerned, in both genera there are only two stages. There is no strict correspondence between the first stage of *Axius* and the same stage of this species, since in the former all the thoracic appendages behind the third maxillipede are developed, while in this they are not. The second stages, however, show the closest correspondence possible in respect of the development of appendages. Another important point of resemblance between this and the Axiidae is the absence of uropods in larval life. Although this is not characteristic of the family, it is quite characteristic of the genus *Axius.* Equally important is the structure of the telson of this form. The broadly triangular shape, the notch in the centre of the posterior edge and the numerous ciliated spines on either side of the median spine are characteristic also of the telson of *Axius.*

These resemblances are such as would most probably be shown by a form which occupies an intermediate position between the two genera *Axius* and *Callianassa.* Thus the development of this species shows characters of both families emphasising the fact that it is impossible "to draw up any definition which will separate the two families." (Gurney.)

Although a *linea thalassinica* is not clearly seen, the possession of such characters as the flattening of the eyes against one another, the characteristic lobe on the hinder edge of the propodite of the third leg, the subchelate last leg and the gill formula show that this form is an undoubted Callianassid. But it is difficult to refer it definitely to any of the sub-genera of *Callianassa.* It cannot be either *Calliactites* or *Scallasis,* because the former has no lobe on the propodus of the third leg and the latter has rounded eyes. Similarly the peculiarities of the uropods and telson and the third maxillipede seem to point to the distinctness of the present form from two more of the remaining sub-genera,

viz., *Cheramus* and *Trypaea.* There remains only one sub-genus now, viz., *Callichirus* with which there is some amount of agreement in respect of the abovementioned parts. I therefore venture to refer it provisionally to this sub-genus hoping to settle the question of its identity at some future date after a study of the adult characters.

Family CALLIANASSIDAE.

Sub-family UPOGEBINAE.*

Larvae of this form have not been found to occur in large numbers in the Madras Plankton. The earlier stages were obtained throughout February and in the beginning of March. The creatures are quite transparent and the light green colour of their body harmonises so well with the prevailing hue of sea-water kept in glass vessels that only careful examination could reveal their presence. The later stages, though not different in colour, are detected with less difficulty owing to their larger size. These were captured on a few occasions towards the close of March.

Stage I, pl. vi, fig. 1.—Total length from tip of rostrum to posterior edge of telson 1·8 mm.

The larva is considerably smaller than the corresponding stages of *Gebiopsis deltaura* Leech and *Upogebia stellata* (Mont.) described by Miss Webb (journal of the Marine Biological Association of the United Kingdom, Vol. XII, 1919-22) and *Upogebia danai*, Miers described by Gurney (1924). As I was not able to obtain Cano's paper on the metamorphosis of *U. littoralis* no comparison with its larval forms can be made here. The carapace is short, broad and smooth, its length being about one-third of the whole body. In front it is produced forwards between the eyes into a moderately long pointed rostrum, the tip of which projects beyond the tip of the antennule. The abdomen is slender, rounded and tapers slightly towards the posterior end. The most important point about the abdomen is the presence of postero-lateral spines in the fourth and fifth somites. Those of the fourth are minute but the other pair are larger and directed obliquely backwards. The presence of spines on the abdominal segments is a unique character of the larvae of this species.

The eyes are large and borne on short stout stalks.

Antennule, pl. vi, fig. 2—Resembles very closely that of the three species mentioned above. It is a simple, unjointed process, rather shorter than the rostrum, carrying at its tip five spines and a broad aesthetis. A short distance below the tip on the inner side there is a single plumose seta.

Antenna, pl. vi, fig. 3.—Like the antennule the antenna also is very similar to that of the same stage of the above-mentioned species. The basal lobe is unjointed and produced into the flagellum, between which and the former there is no suture. The scale is larger

* The identification of this form presents serious difficulties and they are indicated towards the end of the paper.

than the flagellum. Its outer edge is smooth and slightly concave and terminates distally in a large spine. Around the tip and inner edge there are ten long plumose setae, of which the one nearest to the terminal spine is much smaller than the others. Three similar plumose setae are borne by the tip of the flagellum. Ventrally the basal lobe is produced into a spine just behind the junction of the scale and peduncle.

Mandible, pl. vi, fig. 4.—The cutting edge is somewhat different in shape from that of *G. deltaura* figured by Webb. It is convex in the middle and at the two sides there are two or three sharp teeth. There is no palp.

First Maxilla, pl. vi, fig. 5.—The protopodite is produced inwards into two masticatory lobes slightly unequal in size. Each is armed with four-barbed spines, those of the proximal lobe being much shorter than the others. The palp, unlike that of *G. deltaura* and other species is unjointed. It bears three spines which are longer and more slender than those of the basal lobes.

Second Maxilla, pl. vi, fig. 6.—Like the first, the second maxilla also differs in certain important respects. The basal segment has the usual four endites but the most proximal is rudimentary and tipped with a single seta. Each of the other three is armed with four setae at its tip. The palp, like the proximal endite is extremely rudimentary, being little more than a prominence on the distal margin of the distal endite and carries two setae one of which is very small. The scaphognathite is a flat, oval lobe around the tip and outer margin of which are placed five-plumose setae.

First Maxillipede, pl. vi, fig. 7.—The protopodite is two-jointed. The basipodite is much longer than the coxopodite and carries on its inner margin four setae. The exopodite is two-jointed. The joints are almost equal in length and the distal is tipped with four-plumose setae. The endopodite is four-jointed. The third joint is considerably longer than the first and second. A stout seta is present at the distal inner margins of each of the first two joints and a pair of larger ones on the third joint. The last joint is tipped with four setae. On the outer side of this joint a short slender seta is present, but unlike that of *G. deltaura* and *U. stellata* it is not plumose.

Second Maxillipede—Differs from the first only in the absence of some of the setae borne by the first. The first two segments of the endopodite and the basipodite are devoid of setae.

Behind the second maxillipede rudiments of only four succeeding appendages can be made out which decrease in size from before backwards. All of them are uniramous.

Abdomen.—There are only six segments, the last segment not being cut off from the telson. The telson is a broad roughly triangular structure with a distinct, though shallow, median notch in its posterior edge. On either side of this notch there are five ciliated setae. At each outer corner there is a stout spine. Between the outermost seta and the corner spine there is a much reduced hair-like seta which arises from the ventral side of the posterior edge.

There is no trace of any abdominal limb.

As has been already remarked, the larva is perfectly transparent and has got a slight greenish tint. In the fifth segment of the abdomen at the base of the postero-lateral spine there is a large round dark red chromatophore. On the ventral surface just behind the mouth there is another of the same colour.

Stage II, pl. vi, fig. 8.—Total length from tip of rostrum to the posterior edge of telson 2·2 mm.

The general shape of the body has undergone hardly any change. The most important difference between this and the preceding stage is the presence of three setose expodites in the thorax and an additional pair of setae on the posterior edge of the telson. In respect of the development of natatory exopodites this larva does not show as much progress as the corresponding stage of other species. In the case of *G. deltaura* and *U. stellata* Webb distinguished two classes of larvae belonging to this stage, one of which possessed four exopodites with swimming setae and the other five. The second stage of *Upogebia danai* is even more advanced than the two former ones as it has got six fully developed exopodites tipped with plumose setae. The rostrum appears proportionately shorter in this stage since the antenules have grown and both are now equal in length. The minute spines of the fourth abdominal segment have disappeared, but those of the fifth persist and have grown a little. They are present in the three succeeding stages also and it is these spines and the red chromatophores at their base that make them easily distinguishable from larvae of other species of Upogebinae.

The ocular peduncles, the bases of which were fused together in the previous stage are now completely separated.

Antennule, pl. vi, fig. 9.—It is not much changed. There are seven or eight ordinary setae at its tip besides the single aesthetis. The inner plumose seta springs from a distinct, though small, protuberance on the inner margin, which may be the rudiment of the inner flagellum. At the base a swelling has appeared on the outer surface in which the statocyst comes to be lodged later on.

Antenna, pl. vi, fig. 10.—The peduncle is still unjointed and the flagellum is not yet cut off from it. The inner margin of the antennal plate bears twelve plumose setae. In addition to the ventral spine of the peduncle of the last stage, there is another smaller one springing from the outer border of the extremity of the peduncle.

Mandible—Shows no appreciable change.

First Maxilla—Is hardly changed except in size. The distal endite has one more tooth than in the previous stage.

Second Maxilla, pl. vi, fig. 11.—The proximal endite and the palp show little development and carry the same number of setae. The second and fourth endites are still armed with four setae each, but the third has five. The scale is bordered now with seven plumose setae.

First Maxillipede.—The only difference, besides the increase in size, is the increase in the number of plumose setae on the exopodites to six.

Second Maxillipede.—The exopodite has the same number of setae as that of the former. The second joint of the endopodite has one seta on its distal inner margin.

Third Maxillipede.—There is a two-jointed protopodite. The exopodite is similar to those of the other two maxillipedes and is tipped with the same number of plumose setae. An endopodite has not yet developed.

Behind the third maxillipede rudiments of all the legs are developed of which the first three pairs are already biramous. Each of these has a protopodite and two rami, which are unjointed except the exopodite of the first leg, which has two segments. They do not carry setae.

The abdomen still consists of the same six segments which have scarcely altered in shape. No trace of pleopods is seen externally, though small knob-like protuberances are visible beneath the cuticle in segments 2-5. The uropods are not developed.

Telson.—The shape of the telson is the same as in the first stage. The notch on the posterior edge is all but obliterated and one more seta is present on either side of it. There is no median unpaired seta and in this it differs from the telson of the same stage of all the other three species referred to above.

Stage III, pl. vi, fig. 12.—Total length 2·7 mm.

This stage shows a great advance on the previous stage and can be easily recognized by the presence of four natatory exopodites and the uropods. There is little variation from the two preceding stages so far as general appearance is concerned. The rostrum is equal in length to the antennules.

The eyes are very large and the peduncles are quite free as in the last stage.

Antennule, pl. vi, 13—Has grown longer and stouter. A peduncle and two short flagella are now clearly marked out. Along the inner border of the former there are four plumose setae and two more are present at the anterior end. A few short, slender, setae arise from the tip and also from a small prominence on the outer side opposite to the second seta. The swelling at the base has not grown much. The outer flagellum is a sixth as long as the peduncle and bears five setae and two unequal aesthetes at its tip. The inner flagellum is in the form of an oval papilla, about a third of the outer in length.

Antenna, pl. vii, fig. 14.—The peduncle is now two-jointed, the basal joint being much shorter than the other. The flagellum, which is yet not quite so long as the scale, is completely cut off from the peduncle and is tipped with only a short vestigial seta. The number of setae along the inner edge of the scale has increased to thirteen.

Mandible—Remains unchanged.

First Maxilla, pl. vii, fig. 15.—The proximal endite is armed with four teeth as in the preceding two stages, but the distal has seven, three of which are much longer than the other four. The palp is still unjointed and bears the same number of spines at its tip. An additional spine has appeared on the proximal border of its base.

Second Maxilla.—The proximal endite and palp have not grown much and carry the same number of setae. The third endite has six setae, the first and fourth having the same number as in the previous stage. The scale is fringed with nine plumose setae.

First and second Maxillipedes—Show no new character worth mentioning. In both *G. deltaura* and *U. stellata* a plumose seta is present on the outer side of the third joint of the endopodite. (In *U. stellata* it was present in previous stages also.) This is absent in this species.

Third Maxillipede, pl. vii, fig. 16.—The protopodite and exopodite are unaltered. A rudimentary endopodite has been developed as a process from the base of the basipodite. It is about one-third of the basipodite in length and bears no setae.

First Pereiopod.—There is a two-jointed protopodite and an exopodite entirely similar to those of the maxillipedes, armed with six plumose setae. The endopodite is an unjointed process similar to that of the third maxillipede and springing from the base of the basipodite. Its tip projects a little beyond the distal end of the basipodite.

The remaining four legs, except for an increase in size are in the same condition as in the previous stage.

Abdomen.—The last somite is now distinct from the telson and is much longer and narrower than any of the preceding segments. There are as yet no free pleopods, though their rudiments still covered by the cuticle project considerably on the ventral side.

The uropods are, however, free. Each has got a basal segment and two lobes between which and the base there is no definite suture. The exopodite is an oval flattened structure, not quite so long as the telson and bordered round the tip and inner margin with ten plumose setae. The endopodite is smaller, about two-third as long as the exopodite, and bears two setae at its tip.

Telson.—It is roughly oblong in shape, the posterior end being a little broader than the anterior. The posterior edge is slightly concave and the median notch is hardly perceptible. On either side of the median line there are five short ciliated setae and beyond these a large spine. Outside this there is the hair-like reduced seta and a small spine. There is no median spine. In the two species dealt with by Webb and in *U. danai* there are two or three spines on the outer side of the large corner spine and a median spine is also present.

Stage IV, pl. vii, fig. 17.—Total length 3·4 mm.

A great increase has taken place in the size of the animal. There are now five exopodites furnished with swimming setae. The pleopod rudiments have just emerged out from beneath the cuticle. These characters would easily enable this stage to be distinguished from the previous ones. The rostrum has not grown much while the antennules have, so that its tip now reaches only up to the distal end of the antennular peduncle.

Antennule, pl. vii, fig. 18.—The peduncle is still unjointed and the swelling at its base has grown a little. There are six plumose setae along its innerborder and four more arise from the distal end. The outer flagellum has grown and shows three joints imperfectly. The first joint has one and the two others have each two aesthetes. A few slender setae are also present on the last joint. The inner flagellum is still unjointed, half as long as the outer, and has one or two small spine-like processes at its tip.

Antenna.—The flagellum has elongated and its tip now reaches to or projects slightly beyond the anterior end of the scale. It does not show segmentation and the tip still bears the vestigial seta noticed in the last stage. Besides this two short slender setae are present on the inner side of the flagellum. The scale has seventeen plumose setae along its inner edge.

First Maxilla, pl. vii, fig. 19.—The proximal endite has now five and the distal eight spines. The other parts remain unchanged.

Second Maxilla, pl. vii, fig. 20.—Though the proximal endite has grown, it is still tipped with only one seta. The second and third have each six and the fourth five setae. The palp also shows a distinct increase in size. The scale has grown and expanded considerably in an antero-posterior direction and bears fifteen plumose setae. The extreme proximal part of the outer edge is as in *U. danai*, devoid of setae. Though Webb does not mention it in her description, her figure of the appendage of the fourth stage of *G. deltaura* (pl. v, fig. 9) shows the proximal part of the scale quite bare. In this respect these members of the upogebinae resemble the Paguridae and Hippa.

The first and second maxillipedes are practically unchanged. In the third maxillipede the endopodite has elongated a little, being now about two-third as long as the basipodite.

First Pereiopod.—The endopodite is now as long as or slightly longer than the basi and exopodites together. It is much thicker at the distal end, and the rudiment of the future chela is even now developed though the various joints are not marked out.

Second Pereiopod.—There is now a two-jointed exopodite carrying six plumose setae at its tip. The endopodite is quite similar to that of the first leg but has no chela.

Third Pereiopod.—A two-jointed protopodite is distinctly marked out. The exopodite is imperfectly jointed and unarmed. The endopodite shows no segmentation.

Fourth and fifth Pereiopods--Are still uniramous rudiments, though in length they equal the third pereiopod.

Abdomen—Has grown much and tapers considerably towards the posterior end. On the second and the three following somites small bud-like rudiments of pleopods are developed.

Uropods, pl. vii, fig. 21.—The exopodite is shorter than the telson. Its outer margn is devoid of setae and terminates distally in a small spine. Around the tip and inner edge there are thirteen plumose setae. The endopodite is shorter and narrower and bears a fringe of nine plumose setae.

Telson—Has elongated a little. The posterior edge is much less concave than it is in the same stage of the European species. One more pair of small spines have developed in the middle so that now there are altogether eight spines on each side besides the reduced one. In the presence of more than four spines on either side of the posterior edge inner to the corner spine this species differs from both of the European and the New Zealand species.

Stage V, pl. vii, fig. 22.—Total length 4·25 mm. The increase in size is much greater than between any two of the preceding stages. The endopodites of the first three pereiopods have elongated considerably and an exopodite with a pair of swimming setae at its tip is present in the third pereiopod. The pleopods are better developed than in the previous stage and the telson has a median tooth-like spine on its posterior edge.

Antennule—Shows hardly any advance. The inner flagellum is tipped with two well-developed setae instead of the spine-like processes of the last stage.

The antenna, mandible and first maxilla remain unaltered. The distal endite of the last-mentioned appendage has one more spine.

Second Maxilla.—The proximal endite and palp have grown a little more. The former has a short additional seta at its tip. The maxillipedes also are unaltered save for an increase in size.

First Pereiopod.—The endopodite is now much longer than the exopodite. The chela is well formed, the movable finger being separated by a suture from the rest of the endopodite. The other joints are not, however, well marked.

Second Pereiopod.—The endopodite is more than twice as long as the basipodite. Segmentation is obscure—No chela.

Third Pereiopod.—Endopodite similar to that of the second leg.

The exopodite is much shorter than those of the foregoing limbs, and is provided with only two plumose setae, one of which is very short.

Fourth and fifth Pereiopods—Are still uniramous though grown much bigger than in the last stage. They also do not show clearly marked joints.

Gills.—Small round or oval bud-like gill rudiments are developed, a pair at the base of each of the appendages from the second maxillipede to the fourth pereiopod.

Abdomen.—The pleopods have grown and each has now a peduncle and two short lobes (without setae) more or less distinctly marked out.

The uropods show the same characters as those of the previous stage.

Telson, pl. viii, fig. 23.—The shape of the telson is the same as in the last stage and is different from that of *G. deltaura* and *U. stellata* inasmuch as the posterior portion is much broader in this case. The posterior edge is almost straight and in its middle there is a small median spine. On either side of this median spine there are seven spines, so that a pair of the last stage has disappeared in this. The development of the median spine so late in the larval life is an important variation from the development of the afore-mentioned species of Upogebinae.

First Post-larval stage, pl. viii, fig. 24.—The animal is slightly longer than the last larval stage. The carapace does not show lateral compression to any great extent. Anteriorly it is produced between the eyes into a short, triangular, blunt rostrum, the tip of which is almost on a level with the anterior ends of the eyes. It is slightly concave at the posterior end, the corners of which are rounded and is provided with a number of

short marginal setae. A "*linea thalassinica*" seems to be absent, but as in *U. danai* "a distinct transverse cephalic groove" which runs forwards to the anterior margin is present. The abdomen is long and slender.

Antennule, pl. viii, fig. 25—Is much better developed than in any of the three species mentioned above. There is a three-jointed peduncle, the last segment of which is as long as the 1st two together. The swelling at the base noticed in the previous stages, now accommodates the auditory organ. Each joint has a few slender setae; the 1st one having also a stout spine at its anterior outer end as in *G. deltaura.* The outer flagellum is as long as the last joint of the peduncle and consists of six segments. Joints 2-6 have 1-3 aesthetes at the distal ends of their inner border and a few ordinary setae. The first joint has neither setae nor aesthetes. The last joint is much smaller than the others and has only three ordinary setae at the tip. The inner flagellum is much shorter and thinner and shows three faintly indicated joints.

Antenna.—There is a four-jointed peduncle. The vestige of the scale is much more conspicuous than in *G. deltaura* and *U. danai* and is in the form of a short, unarmed, finger-shaped process arising from the outside of the distal end of the second joint. The flagellum consists of 22 joints, each of which is armed with a ring of setae.

Mandible, pl. viii, fig. 26.—There is now a short, thick, two-jointed palp which has nine slender pointed spines terminally. The cutting edge has a number of small conical teeth.

First Maxilla, pl. viii, fig. 27.—The two endites do not differ so much in size as those of *G. deltaura.* The basal one is armed with numerous short setae. The distal has a number of sout teeth proximally and a few setae at the distal end. The palp as in *G. deltaura* and *U. stellata* is a finger-shaped unarmed process.

Second Maxilla, pl. viii, fig. 28.—There are four masticatory lobes, the middle two of which are considerably smaller than the outer ones. Unlike those of *G. deltaura* all the lobes are set with numerous setae. The palp is a slender process bearing only one seta. The scale is different from those of all the other three species mentioned in having plumose setae on the proximal inner margin.

First Maxillipede, pl. viii, fig. 29.—The protopodite as usual is produced inwards into two masticatory lobes, the proximal of which bears a few setae on the distal portion of its inner margin. The other is set with shorter setae rather closely. There is a two-jointed palp both joints of which carry a few plumose setae. The exopodite is also two-jointed. On the outer border of the proximal joint there are 6-7 plumose setae and the distal joint as in the earlier stages bears six plumose setae terminally. In the possession jointed endopodites and exopodites, the former of which is armed with plumose setae, this larva differs from similar larvae of the other species.

Second Maxillipede, pl. viii, fig. 30.—The protopodite unlike that of the same appendage in the first post-larva of *G. deltaura* is two-jointed both joints of which bear a number of setae on their inner border. The palp is only four-jointed while in the other species it is

five-jointed. The first joint is the longest and it bears several setae on its inner margin. The other three joints are together about as long as the first and are bent almost to form a right angle with it. Except the second, the other two bear numerous setae at their distal ends. The exopodite as in the first is two-jointed. The first joint carries a cluster of short setae at its distal outer angle and a single plumose seta on its inner margin and the distal joint is tipped with six plumose setae. The coxopodite bears two gills and an elongated epipodite which bears a couple of setae at its extremity. An epipodite has not been noticed in this or any other appendage in the other three species except in *U. danai* in which a rudimentary one is present on the third maxillipede.

Third Maxillipede, pl. viii, fig. 31—Is uniramous. There are altogether seven joints; the basal joint as in the preceding limb has two gills and an epipodite. The third joint is the longest. All of them are well armed with setae especially on the inner border. The third has, in addition to these setae, four or five triangular teeth on its inner margin.

First leg—Is chelate. The left chelipede (pl. viii, fig. 32), is larger than the right (pl. viii, fig. 33), and in this character this species presents an important variation from *G. deltaura.* The appendage is seven-jointed. The basal joint carries two branchiae and an epipodite as in the two preceding appendages. The third, fourth and fifth segments are comparatively slender, while the sixth is much broader, its distal part forming the fixed finger of the chela. The dactylus in both is larger in size than the fixed finger. All the joints are armed with setae, which are particularly numerous and larger along the inner border. A few setae are present on the inner edges of the fingers of the chelae. In the larger chelae the movable finger has two and the other 6–7 large triangular tubercles; in the other the former has four and the latter seven smaller tubercles.

Second leg, pl. viii, fig. 34.—The coxopodite, as in the preceding limbs has a small epipodite and two branchiae. The basipodite is much smaller than the coxa. All joints are somewhat slender, the second being the longest. The terminal joint is shaped like a knife-blade. Along both the inner and outer borders there are numerous long setae.

Third, fourth and fifth legs.—The three following legs are similar to the second, but thinner and each consists of seven joints. The third and fourth have each two gills on the outside of the coxopodite, the fifth having none. A small epipodite is present on the third, but is absent from the fourth and fifth. These have fewer setae on the joints than the second leg. In the third and fourth legs, on the anterior border of the last joint, there are stout conical teeth, one in the former and two in the latter. Besides these on the third, fourth and fifth legs at about the middle of the posterior border of the dactylopodite there are some smaller teeth, four or five in the two front ones and more than twice that number in the last.

Abdomen.—The first five segments of the abdomen are almost equal in length, the last being longer than these. The pleura are fairly well developed. Somites 2–5 bear pleopods. Each pleopod (pl. viii, fig. 35) has an unjointed peduncle and two flattened lobes of which the inner one is slightly smaller, but not so much as in the European and New Zealand species mentioned above. They are fringed on both borders with long plumose

setae. Arising from the inner border of the base of the endopodites there are quite well-developed appendices interna each of which bears at its tip three hook-like retinacula. The presence of appendices interna in all pleopods of this form is unique and it seems to be the result of the large size of the endopodites, in the other species the small transversely directed endopodites being themselves able to interlock with those of the opposite side by means of their setae.

The Uropods, pl. viii, fig. 36.—The external and internal lobes of the uropods are narrower than those in the other species referred. They are oval in shape, the outer being a little broader than the inner. Both are surrounded by plumose setae along their margin except the proximal part of the outer edge of the endopodite.

Telson.—The telson is almost rectangular in shape. Along the posterior edge and the distal parts of the lateral margins, there are a number of plumose setae.

The more important variations of these larvae from the larvae of other forms, that have been already indicated in the foregoing account, may be summarised as follows:—

(1) None of the three species mentioned above pass through more than four larval stages and in each case some of the larvae in the third stage metamorphose directly into the post-larval stage. In this case there are five distinct stages and only specimens of the fifth stage have been noticed to change into the post-larval form.

(2) The presence of lateral spines on abdominal somites. In no stage do the larvae of the other species possess any spines on the abdominal somites.

(3) The very late appearance (viz., in the last larval stage) of the median spine on the posterior edge of the telson. In every one of the other species this median spine makes its appearance in the second stage.

(4) The presence of epipodites in the two posterior maxillipedes and the first three pereiopods in the post-larval stage. No mention is made of an epipodite as occurring in any of these appendages in the post-larval stages of the other species except in *U. danai* referred to already.

(5) The possession of well-developed appendices interna carrying retinacula at their tips by all the pleopods, which is also, as has been already remarked elsewhere, unique in this form.

The following is a list of the distinguishing characters of the larvae of Upogebinae as drawn up by Gurney (1924):—

(1) Rostrum very small, not flattened horizontally.

(2) Abdominal somites without dorsal or lateral spines.

(3) Telson with reduced second seta and in later stages with a small median spine. Fourth spine largest in later stages.

(4) Mandible without palp.

(5) Two pairs of biramous maxillipedes present on hatching. Legs 1-3 develop exopodites.

(6) Pleopods absent from abdominal somite one only.

(7) Endopodite of third maxillipede rudimentary and springs from the base of basipodite.

It will be seen that most of the characters mentioned in the above list are shown by these larvae also, so that we have necessarily to consider them as belonging to some form of the sub-family Upogebinæ. But the presence of such characters as mastigobranchs on thoracic appendages 2-6 and appendix interna on all pleopods in the post larval stage would prevent its inclusion in that sub-family, which according to Borradaile (1903) is characterized by their absence. Further the chelae of the first leg of this form are unequal whereas they are equal in all other forms included in the sub-family. It cannot, on the other hand, be included in any of the other families belonging to the order Thalassinidea since it shows much less agreement with them. As I have not been able to obtain the adult animal, it is impossible to say at present whether any of the above-mentioned characters become modified during the subsequent growth of the animal and so the identification of it has to be left for future work.

Family HIPPIDAE.

Hippa asiatica, Milne Edwards.

Hippa asiatica--Is one of the commonest Decapod Crustaceans of the Madras coast. They are usually found inhabiting the lose sand near the low water mark, at which place some of these animals can frequently be seen rapidly burrowing down soon after a wave has receded, by the action of which they had been exposed. The only other member of the Hippidae recorded from this coast is *Albunea symnista*, which is a much larger form and does not occur in such large numbers as the former. An account of the habits of the American form *Hippa emerita* (talpoida) is given by S. I. Smith in his paper "The early stages of *Hippa talpoida*, with a note on the structure of the mandibles and maxillae in *Hippa* and *Remipes*" (*Trans. Conn. Acad.*, 1877).

Females of *Hippa asiatica* carrying eggs can be obtained from September onwards throughout the following eight or nine months, though specimens with mature eggs were secured only in December. But, for reasons suggested in the introduction, it was not possible to get the earliest stage hatched in the laboratory. The eggs are of a beautiful orange colour and about ·4 mm. in diameter. The larvae of *Hippa* were present in varying numbers in the plankton from September to March. In September and the following two months only a few belonging to the early stages were present. But in December, January and February large numbers of the larvae in the first stage were collected. The next two or three stages were also present, but only in much smaller numbers. Towards the close of February and early in March the later stages were quite common and were obtained along with the earlier stages which were still present, and continued to be present, though in steadily decreasing numbers, till the end of March, after which they were practically absent. In the beginning of March fully developed young specimens were quite abundant on the coast in the same place as that inhabited by the adults.

It was Smith who first undertook the study of the larval development of *Hippa.* His paper contains exhaustive descriptions with good figures of three larval and the first post larval stages of the American species *H. talpoida* with an account, especially of the abdominal appendages, of some stages succeeding the first post-larval. He got all his stages from the plankton, the earliest of which be regarded as belonging to the second stage, though he has given no reasons for it. Walter Faxon in 1878 (On some young stages in the development of *Hippa, Porcellana* and *Pinnixia,* Bulletin of the Museum of Comparative Zoology, 1878–79) figured and described the first stage of the same species, which he was able to get hatched out from ripe eggs in the laboratory, and thus proved that the larva figured in Fritz Müller's " Fur Darwin " was really the first stage of *Hippa* and not an " imperfectly developed young zoea in which the rostrum and lateral spines were not expanded," as was remarked by Smith. From the fact that the first stage possesses only a short and blunt rostrum and no lateral spines, while the earliest stage of Smith has both of these well developed, Faxon correctly inferred that the so-called second stage of Smith was " in reality a later one in the development " and thought " that one, if not more stages remain to be discovered " between the first stage and the earliest described by Smith.

As I have been able to secure from the plankton the stage (there is only one) which intervenes between the first stage and the so-called second stage of Smith, I am now enabled to give a complete account of the larval development of the Asiatic species. Five larval and the first post-larval stages are described of which the third closely corresponds to the second stage of Smith. A table is added at the end showing the differences between the five zoea stages of the two species.

Stage I, pl. ix, fig. 1.—Total length 2 mm.

In shape and general appearance the larva is remarkably similar to that described by Faxon (pl. I, figs. 5 and 6). The animal, except when swimming, is almost round, since the abdomen is closely pressed against the ventral surface of the thorax. The carapace is smooth and curves downwards and inwards on the sides. Anteriorly it is produced between the eye stalks into a short conical blunt rostrum. The anterolateral portion on either side sends a long process forward below the eye stalks, the tip of which is in contact with the base of the antenna. The lateral spines of the later stages are not present, but at the points where they arise in the next stage there is a small swelling.

Eyes are stalked and in the horizontal position project slightly beyond the carapace.

Antennule, pl. ix, fig. 2—Is a short, thick, unjointed process tipped with three aesthetes of which one is larger than the others. The rudiment of the secondary flagellum, which was noticed in some specimens by Faxon is totally absent in this and makes its appearance for the first time only in the first post-larval stage as Smith has already observed.

Antenna, pl. ix, fig. 3—Is also an unjointed process equal to the antennule in length, but does not taper distally. At its extremity it carries two processes, which Smith calls dentiform processes, the inner of which is thinner than the outer. The rounded

prominence shown by Faxon in his figure (C, pl. i, fig. 9), is not seen in this. At the base of the processes and opposite to the inner one there is a small sharp spine which persists in all the four succeeding stages, though in the fifth it is so much reduced as to be hardly visible.

The labrum is not much different from that of *H. talpoida*, but the lobes of the labium are separated by a much wider interval (pl. ix, fig. 4).

Mandible, pl. ix, fig. 5.—The cutting edge is armed with 6–8 teeth, of which the ventral two are stout and blunt, while the others are slender and pointed.

First Maxilla, pl. ix, fig. 6—Is somewhat similar to that of *H. talpoida.* There are two endites, of which the inner is much smaller than the outer, and is armed terminally with three slender setae (one less than in *H. talpoda*). Below these and on the inner margin there is a minute rudiment of another seta. This shows very little growth in all the four succeeding stages. The outer lobe has got only two setae, which do not, however, show so much difference in size as in Faxon's fig. (pl. I, fig. 11). Only the inner seta is articulated, the other being a sort of continuation of the lobe itself as in *H. talpoida.* There is a short palp armed at the tip with a single seta.

Second Maxilla, pl. ix, fig. 7—Is very imperfectly developed as in *H. talpoida.* The protopodite has only a single lobe tipped with three setae. On the inner side somewhat above the middle and arising not exactly from the margin there is a rudimentary seta similar to that of the first maxilla. Like the latter it persists with little change in size in all the four succeeding stages. There is a scaphognathite, the anterior end of which projects beyond the tip of the protopodite. About three-fourths of its outer border from the anterior end is fringed with 9 or 10 plumose setae, the remaining fourth of which and the posterior border being devoid of them. In Faxon's figure of the same appendage (pl. I, fig. 12) the numbers of setae in the protopodite and scale are four and eleven respectively, and what is of greater importance is that the fringe of plumose setae extends to the posterior end of the outer border of the scale. However, it does not seem to be correctly drawn, since, in the third stage of the same species (second stage of Smith, pl. xlvii, fig. 1) the hind-most part of the outer edge does not bear setae. It may be of interest here to observe that in the Paguridea also the proximal part of the scale is bare.

First Maxillipede, pl. ix, fig. 8.—The protopodite is two-jointed, the basipodite being much longer than the coxopodite, and even the exopodites. The former is armed along the inner margin with six or seven short setae. The endopodite is four jointed. The first joint is armed with two or three and the next two each armed with a couple of short setae at their distal inner margin, and the last joint, which is much smaller, is armed with four at the tip, two of which are much longer than the others. These and one of the shorter ones carry minute spinules along one side. The exopodite is slightly longer than the endopodite and carry four long plumose setae at the tip.

Second Maxillipede.—Closely similar to the first. The endopodite is a little longer than the exopodite, but in other respects is similar to that of the first. The basipodite has only three short setae on its inner border.

Behind the second maxillipede there is no trace of any other appendage.

The abdomen consists of only five segments including the telson. The first two segments are equal in size and almost cylindrical. The third and fourth are shorter and they, especially the latter, widen considerably towards their posterior ends. They are devoid of any vestige of appendages.

Telson, pl. ix, fig. 9—Is somewhat different in shape from that of *H. talpoida.* Its length is slightly in excess of its breadth and the greatest width is reached about its middle. The posterior edge is strongly convex and is armed with 26 spines, besides the two stout spines at the corners. Of these, the eighth from the side is the largest as in *H. talpoida.* Between the spines there are varying numbers of denticles. In some specimens there are 38 of them arranged in the same way as in *H. talpoida,* but in some others there are 41. The number of denticles in this as well as in the succeeding stages does not seem to be constant.

The larva is perfectly transparent except for the presence of a few bright orange coloured chromatophores. There are two such chromatophores near the anterior edge, and one on either side of the posterior part of the carapace.

Stage II, pl. ix, fig. 10.—Total length from tip of rostrum to posterior border of telson 3·75 mm. The animal has grown much. The rostrum has elongated into a long, slender, tapering process and a pair of lateral spines have appeared at the posterior end of the carapace which are almost two-third the rostrum in length.

Antennule—Shows no difference from that of the previous stage except a slight increase in size.

Antenna, pl. ix, fig. 11.—Besides the increase in size, a small spine has appeared at the tip of the external dentiform process. Otherwise there is no change from that of the first stage.

Mandible.—No appreciable advance on the preceding stage.

First Maxilla, pl. ix, fig. 12.—The inner lobe does not show any change. The outer is now armed at the tip with three setae of which the outermost does not show any articulation with the lobe itself. Palp remains unchanged. This appendage persists in this condition with hardly any change except in size to the last free swimming larval stage.

Second Maxilla.—Same as in the previous stage.

First and second Maxillipedes.—The protopodites and endopodites are, but for the slight increase in size, exactly as they were in the first stage. The exopodites are now tipped with six plumose setae.

Behind the second maxillipedes there is no rudiment of any other appendage.

Abdomen—Still consists of only five segments which do not show any change in appearance. No appendages are present on any of them.

Telson.—The shape has undergone no change and it is retained in the subsequent stages also. Number of spines remains the same. But the number of denticles has increased to about 50. The arrangement of these is not symmetrical on both sides.

Colouration in this as well as the succeeding free swimming stages is the same as that of the first.

Stage III, pl. ix, fig. 13.—Length of the animal in this stage is 4-5 mm. The most important differences between this and the second stage is the increase in the number of plumose setae of the exopodites of the maxillipedes to eight and the development of the uropods. As has been already observed this stage corresponds to stage II of smith (pl. xlv, fig. 1) with which it shows remarkable similarities.

Antennule—Is still unjointed and carries three unequal aesthetes at its tip.

Antenna, pl. ix, fig. 14.—A knob-like rudiment of the future flagellum is now developed on the inner side of the tip of the peduncle. The outer dentiform process has now three small spines at its tip and the inner has one.

Mandible, pl. ix. fig. 15—Is very similar to that of *H. talpoida.* There are now ten teeth on the cutting edge, of which four on the ventral half are blunt and conical, while the others are slender and pointed. It persists in this condition with practically no change in the two following stages also.

First Maxilla.—No difference from that of stage II. Smith says that the palp is provided with a plumose seta in his specimen. But in all stages of the present form this seta is similar to those of the outer lobe.

Second Maxilla, pl. ix, fig. 16.—The protopodite lobe has still only three setae at its tip. The scale is bordered now with eleven or twelve plumose setae which do not, however, extend to the extreme posterior end of the outer margin. The posterior margin is still devoid of them.

First and second Maxillipedes.—The exopodites are provided with eight plumose setae at their extremities. The other parts do not show any change.

Behind the second maxillipedes there are rudiments of all the other posterior thoracic appendages. The rudiments of the last pair are, however, very small and since they lie entirely below the rudiments of the fourth, are invisible when viewed from above. Above each of the first three leg rudiments a small rudimentary gill has appeared.

Abdomen—Consists of the same number of segments. Traces of pleopods are as yet not visible, but the uropods have developed (pl. ix, fig. 17). They are entirely hidden by the telson from above. Each is uniramous with a stout unjointed basal segment and a slender lobe which is the exopodite. It bears two setae at its tip of which the inner one is longer than the outer.

Telson.—Number of spines is still the same. Denticles are not arranged, symmetrically on both sides. The total number of denticles is about 100 though it is very variable in different specimens.

Stage IV.—Total length 6·5 mm.

The presence of ten plumose setae on the exopodites and the more advanced uropods would enable one to easily distinguish this stage from the previous one. It corresponds to the third stage of Smith.

Antennule, pl. ix, fig. 18.—Still no differentiation into peduncle and flagellum. The number of aesthetes has now increased to five, two more having developed on the inner side close to the terminal ones. In addition to these there is a couple of very slender setae at the tip. No indication of segmentation could be made out.

Antenna, pl. ix, fig. 19.—The rudimentary flagellum has elongated considerably and is now slightly longer than the dentiform processes, the outer of which has three or four spines and the inner two at their tips. It is, however, unjointed.

Mandible—Does not show any change.

First Maxilla.—Same as in the previous stages.

Second Maxilla, pl. x, fig. 20.—The anterior end of the scale hardly projects beyond the protopodite. The fringe of plumose setae, 21–26 in number, on the outer edge of the scaphognathite extends almost to its hind end. There are still no setae on the posterior edge.

First and second Maxillipedes.—These differ from those of the previous stage only in the exopodites, which are tipped with ten plumose setae. The rudiments of the remaining appendages which were present in the last stage have grown, and all except the last are curled up. The rudiment of the third maxillipede is much thinner than those of the legs. The first three leg rudiments already show imperfectly the last two segments arranged in the manner characteristic of the adult (pl. x, fig. 21). The last leg rudiment is still hidden under the fourth and does not show segmentation. Above each of the first four pair of legs there is now a pair of rudimentary gills.

Abdomen—Still consists of only five segments, which have much the same appearance as in the preceding stages. Very slight protuberances on their ventral sides, which are the rudiments of pleopods, are present.

Uropods, pl. x, fig. 22.—These are much better developed than in the previous stage. The exopodites are much longer and are armed with five setae at their tips. These setae are of unequal length, the outermost is about three-fourth the exopodite, the second is as long, and the third, which is the longest, is much longer than the exopodite. The inner two are considerably shorter than the exopodite. A knob-like endopodite has also developed.

Telson.—Number of spines remains the same. There are more denticles than in the previous stage, but the number is highly variable.

Stage V, pl. x, fig. 23.—Total length 8·5 mm.

This stage, the last free swimming larval stage shows very great advance on the preceding stage, inasmuch as all the abdominal segments are provided with pleopods. The exopodites of the maxillipedes are armed with 12 plumose setae. In appearance it is hardly different from the same stage of *H. talpoida* (Smith's fig. 4, pl. xlv).

Antennule, pl. x, fig. 24—Shows segmentation imperfectly, the outer cuticle not being affected by it. It is divided into nine segments. The number of aesthetes has now increased to ten, three on each of the last and penultimate joints, and two each on the two

segments below. The terminal joint has one or two slender setae also in addition to the aesthetes. There is, however, no demarcation of the peduncle from the flagellum. Rudiment of the secondary flagellum is still absent.

Antenna, pl. x, fig. 25. The flagellum has elongated considerably, being now about thrice as long as the dentiform processes. It is segmented, but the segmentation, as in the case of the antennule, is not visible on the surface as the investing cuticle is not affected by it. The outer dentiform process has five and the inner three spines. In this also the flagellum and peduncle are not clearly separated, but there is a distinct joint at the origin of the dentiform processes, which is assumed by Smith to be the articulation between the second and third joints of the peduncle of the adult appendage.

Mandible.—Similar to that of the previous stage.

First Maxilla—Shows no change.

Second Maxilla, pl. x, fig. 26.—The protopodite as observed by Smith shows a faint indication of segmentation into two lobes. It is till armed with the same number of setae. The outer margin of the Scaphognathite has now 33–40 plumose setae. The posterior edge is still bare.

First and second Maxillipedes—Differ from those of the previous stage in so far as the number of plumose setae on the exopodites has increased to twelve.

The rudiments of all the posterior appendages have grown much more, though they are still curled up as in the last stage. All of them show segmentation, hough imperfectly. In the fourth leg the propodite does not show the process which projects on the inner side of the dactylus as in the three anterior legs. The last leg is still considerably smaller than the others. But all joints are marked off in it, though faintly, and the tip already shows rudiments of the adult chela (pl. x, fig. 27). The number of gill rudiments remains the same and is one less than the number in the adult.

Abdomen—Still consists of only four segments besides the telson. All the segments bear pleopodal rudiments. Each is uniramous and indistinctly segmented into a basal peduncular portion and a lobe which is unarmed.

Uropods, pl. x, fig. 28—Have grown much more than they were in the previous stage. The endopodite has grown considerably and is now about three-fourth the exopodite in length. Both are narrow, flattened, oval structures The exopodite bears at its tip seven setae. The innermost seta is the shortest as in the previous stage, and the others gradually increase in length till the fifth which is the longest. The sixth is much shorter than the fifth, but longer than the seventh. The endopodite is unarmed.

Telson.—Number of spines same. Number of denticles has increased but varies in different specimens. There is one difference in respect of this between the American and Indian species. Smith says that in the interval between the last spine and the spine at the angle there were 30–40 denticles in his specimen. In none of the specimens of this stage examined by me did the number exceed twenty.

First Post-larval stage.—Specimens of this stage were obtained by keeping larvae of the preceding stage in sea-water. The moulting in all cases was accomplished within twenty-four hours. The larva is about 5·5 mm. in length, the abdomen being a little shorter than the thorax. The size is thus the same as that of *H. talpoida*, and the appearance also is exactly similar. The cervical groove on the carapace is clearly visible in this form. As no mention of this is found in Smith's account and as it is not represented in his figure of the anterior end of the animal (pl. xlv, fig. 5) it might probably be absent in *H. talpoida* at this stage. Eyes are similar to those of *H. talpoida*.

Antennule, pl. x, fig. 29.—The peduncle and its segments as well as the two flagella are developed in the same way as in *H. talpoida*. The upper flagellum has eight joints. The rudiment of the lower flagellum differs from that of the American form in that it is armed with two setae, both of which are not plumose. The segments of the upper beginning from the third have each three setae springing from the distal end of their lower margins. The second has only one and the first has none. On segments 5–8 besides the setae four aesthetes also are present in each.

Antenna.—The joints of the peduncle show the same arrangement as described by Smith (Smith's figs. 7, 7 (*a*), pl. xlvi). The flagellum is shorter consisting of about twenty joints. The joints are, however, provided with setae in the same way (Smith's fig. 6, pl. xlv). The labrum and the different parts of the mandible present no differences from those of *H. talpoida* (Smith's fig. 8, pl. xlvi). Extending along each side of the labrum there are five or six long setae which arise from the epistome, not, however, from any process as is the case in the adult *H. asiatica*. Smith does not mention the presence of these and therefore they are apparently absent in the corresponding stage of *H. talpoida*. The lobes of the labium are as in the early stages placed wide apart.

First Maxilla, pl. x, fig. 30—Agrees in all essential respects with that of *H. talpoida* (Smith's pl. xlvi, fig. 13). The difference in width of the proximal and distal lobes is not very considerable as in the American form. The long distal seta of the distal lobe is not so long, being slightly more than half as long again as the width of the lobe. There is no spine on the outer margin of the distal lobe. The shape of the palp is somewhat different and on its outer margin at about the middle there is a minute tooth.

Second Maxilla.—Like the former closely similar to that of *H. talpoida* (Smith's fig. 3, pl. xlvii). The protopodite has the same two endites with a smaller one between them springing from the base of the proximal lobe, and armed with one plumose seta at the tip. The setae on the proximal endite are not all plumose. The palp is an unjointed, very short process. The posterior edge of the scale also bears plumose setae which number about 90. The maxillipedes are also similar to those of Smith's specimen.

First Maxillipede, pl. x, fig. 31 (Smith's pl. xlvii, fig. 4).—The distal lobe of the protopodite is armed with several rows of closely arranged setae, some of which are plumose. The slender unsegmented and unarmed endopodite springs from the middle of the proximal joint of the exopodite. Its distal joint is very much broader than the proximal, thus differing from that of *H. talpoida*, in which both are equally broad.

Second Maxillipede.—Practically no difference from that of the American form.

Third Maxillipede.—Also similar in both species. The inner border of the last three joints is set very closely with plumose setae.

The legs show no difference from those of *H. talpoida*. The chela of the last leg is small, the movable finger being much narrower than the other.

Abdomen—Shows practically no difference in both species. The first segment is much reduced and limbless. Segments 2–6 have well-developed appendages. The pleopods have well-developed protopodites and exopodites, pl. x, fig. 32. The endopodite is considerably smaller even in the fifth segment and is unarmed; in the second segment it is little more than a papilla. The exopodites are bordered with 12–16 plumose setae.

The uropods are also alike in both species.

The colouration is somewhat different from that of the preceding stages. On the dorsal side at the anterior end there is on each side an oblique red band which meets one another at an obtuse angle, a little below the cervical groove. The posterior end of the sixth abdominal segment contains a red, branching chromatophore, from which a branch runs into the antero-lateral part of the telson.

Several specimens belonging to stages later than the preceding were collected with a view to examine them and ascertain the nature of the changes the abdominal appendages undergo during this period of development. In numerous specimens of young *H. talpoida* in which the carapace measured less than 7 mm. in length Smith was not able to detect even vestiges of the first five abdominal limbs. Those of 2–4, however, reappeared in a much reduced state in some specimens (probably females) with a carapace length of 7 mm. His observations admit of only one interpretation and that, in his own words, is that "the egg-bearing appendages of the adult *Hippa* are special developments, and not metamorphosed from the swimming legs of the megalopa stage." The disappearance of these abdominal limbs takes place suddenly in a single moult. The smallest specimen examined by me was scarcely bigger than the first post-larval stage. This together with the slight advance shown by the other parts may reasonably be taken to indicate that the specimen is in the next stage of development. All the abdominal limbs that were present in the post-larval stage are present in this also. But, as the figure would indicate, they are much reduced and are clearly undergoing degeneration, pl. x, fig. 33. The cuticle is very much wrinkled and the whole appendage has a shrivelled up appearance. In another specimen which has a carapace length of 3·5 mm. the degeneration which had set in in the previous stage has proceeded still further. The second pleopod is now a two jointed, uniramous, unarmed structure, pl. x, fig. 34. The third, fourth and fifth become successively shorter, the shortening being the result of the gradual reduction of the distal joint. These are also devoid of setae or any other kind of armature. In a still more advanced stage in which the carapace measured 4·5 mm. those of the second and third segments persisted in the form of minute papillae while those of the other segments have almost disappeared. Even these vestiges have disappeared in a slightly larger specimen

(carapace a little over 5 mm.) so that at this stage all the abdominal segments, save the last, are without appendages. There is no specimen in the collection belonging to any stage later than the last-mentioned one, so that it is not known at what stage the adult appendages make their appearance again. The really important fact, however, about the post-larval development of *H. asiatica* is the gradual degeneration and disappearance of the abdominal appendages as contrasted with their apparently sudden disappearance in *H. talpoida*. The specimens in which Smith first noted the absence of these limbs showed a carapace length of 4·5 mm. and the antennules are much more advanced than those of the second post-larval stage of this form which has a carapace hardly longer than it is in the first post-larval stage. Since the first post-larval stage of both species does not show any variation in size of the carapace, it is very doubtful whether the stage considered by Smith as "next succeeding the megalops," is really that It might probably have been some later stage, the earlier stage or stages of which were unnoticed by him. If that were true, there is every reason to believe that in the development of the American species also the pleopods, instead of disappearing abruptly in a single moult, gradually degenerate and disappear as in the case of the Indian species.

Appendage.	*Species.*	*Stage I.*	*Stage II.*	*Stage III.*	*Stage IV.*	*Stage V.*
Antennule.	H. talpoida.	Rudiment of secondary flagellum present in some specimens.	...	...	2 or 3 distal segments of flagellum faintly indicated.	Segmentation clearly marked on the outside.
	H. asiatica....	Rudiment absent.	...	...	So segmentation visible.	Segmentation imperfect and not on the surface.
Antenna.	H. talpoida.	Two unarmed dentiform processes. Rudimentary flagellum hardly perceptible.	...	Knob-like rudiment of flagellum present. Outer and inner dentiform processes with one spine each.	Rudiment of flagellum a little longer than dentiform processes. Each dentiform process has 2–3 spines.	Dentiform processes armed as in stage IV.
	H. asiatica ...	Dentiform processes unarmed. A spine at the base of inner dentiform process present. Rudiment of flagellum absent.	A small spine present on the external dentiform process.	Rudiment of flagellum present. Outer has 3 and inner has 1 spines.	Rudiment of flagellum same as in H. talpoida. Outer has 3–4 and inner 2 spines.	Outer dentiform process has 5 and inner 3 spines.
1st Maxilla.	H. talpoida.	Inner lobe has 4 almost equal setae at the tip. Setae on outer lobe very unequal in size.	...	Palp with one long plumose seta.	...	...

Appendage.	*Species.*	*Stage I.*	*Stage II.*	*Stage III.*	*Stage IV.*	*Stage V.*
1st Maxilla —*cont.*	H. asiatica ...	Inner lobe has 3 setae at tip and a rudimentary one on the inner margin. Setae on outer lobe only slightly different in size.	...	Seta of palp not plumose.	...	...
2nd Maxilla.	H. talpoida.	Inner lobe has 4 setae. Whole outer margin of scale fringed with plumose setae.	...	...	...	...
	H. asiatica ...	Inner lobe has 3 ordinary and a rudimentary setae. Proximal part of outer border of scale bare.	...	...	...	Fringe of plumose setae extends to the proximal end of the outer margin.
Pereiopods.	H. talpoida.	No appendage behind second maxillipede.	...	Rudiments of maxillipedes 3 and legs 1-4 present. 4 gill rudiments.	Rudiments of third maxillipedes and legs 1-5 present. Segmentation faintly indicated within four pairs of gills.	Last leg shows no indication of its chelate nature.
	H. asiatica ...	Do.	...	Rudiments of all appendages behind second maxillipede present. Only 3 gill rudiments were noticed.	Leg rudiments 1-4 show segmentation distally. 4 pairs of gills.	Last leg shows an imperfect chela.
Uropods ...	H. talpoida.	.....	...	...	4 setae at the tip of the exopodite.	30—40 denticles between first spine and corner spine in telson. 6 setae at the tip of the exopodite.
	H. asiatica ...	.....	...	...	5 setae at the tip of exopodite.	Not more than 20 denticles. 7 setae at the tip of the exopodite.

REFERENCES.

1. BATE, C. S.—1888. Report on the Scientific Results of the Exploring Expedition of H.M.S. "Challenger" Crustacea Macrura.

2. BORRADAILE, L. A.—1903. On the Classification of the Thalassinidea. *Ann. Mag. Nat. Hist.*, XII, 1903.

3. BROOKS, W. K.—1882. Lucifer, a Study in Morphology. *Phil. Trans. R. Soc, London*, CLXXIII, 1882.

4. EDWARDS, A. MILNE, 1830. *Ann. Sci. Nat.*

5. FAXON, W.—1879. On some Young Stages in the Development of Hippa, Porcellana and Pinnixia. *Bull. Mus. Comp. Zool., Harv.*, V.

6. GURNEY, R.—1924. Decapod Larvae. Report of the British Antarctic *Terra Nova* Expedition.

7. HANSEN, H. J.—1919. The Sergestidae of the Siboga Expedition. *Siboga Expeditie*, XXXVIII.

8. HENDERSON, H. J.—1893. A Contribution to Indian Carcinology. *Trans. Linn. Soc.* (2) V.

9. MULLER, F.—Facts and Arguments for Darwin.

10. SMITH, S. T.—1887. The Early Stages of Hippa talpoida, with a Note on the Structure of the Mandibles of Hippa and Remipes. *Trans. Conn. Acad. Sc.*

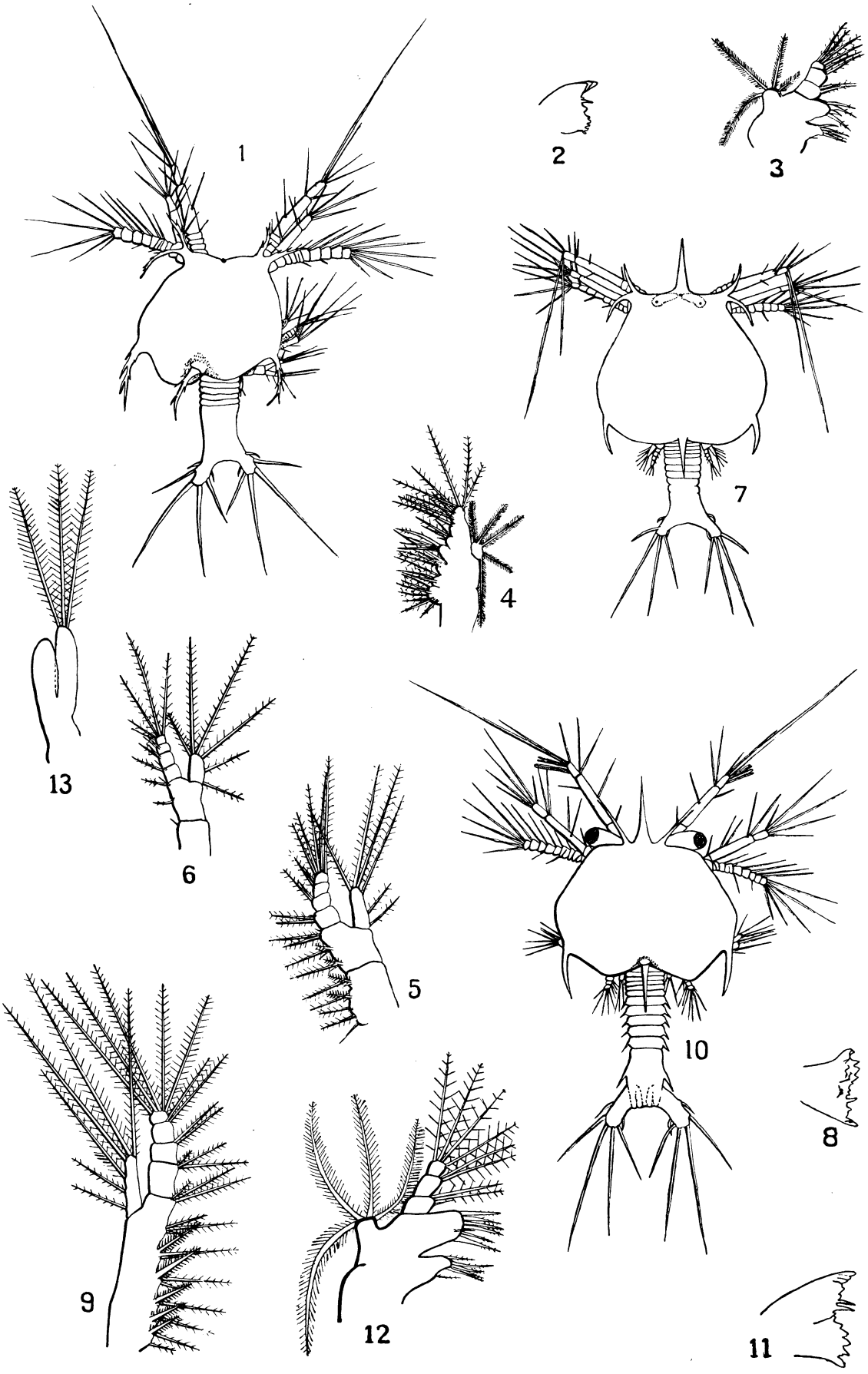
11. WEBB, Miss G. E.—1919. The Development of the Species of Upogebia from Plymouth Sound. *J. Mar. Biol. Ass.* (n.s.), XII.

PLATE I.

ACETES ERYTHRAEUS.

Fig 1. First protozoea stage. × 65
„ 2. Mandible of stage 1. × 150
„ 3. First maxilla do. × 150
„ 4. Second maxilla do. × 150
„ 5. First maxillipede do. × 150
„ 6. Second maxillipede do. × 150
„ 7. Second protozoea stage. × 35

Fig. 8. Mandible of stage 2. × 150
„ 9. First maxillipede do. × 150
„ 10. Third protozoea stage. × 30
„ 11. Mandible of stage 3. × 150
„ 12. First maxilla do. × 150
„ 13. Third maxillipede do. × 150

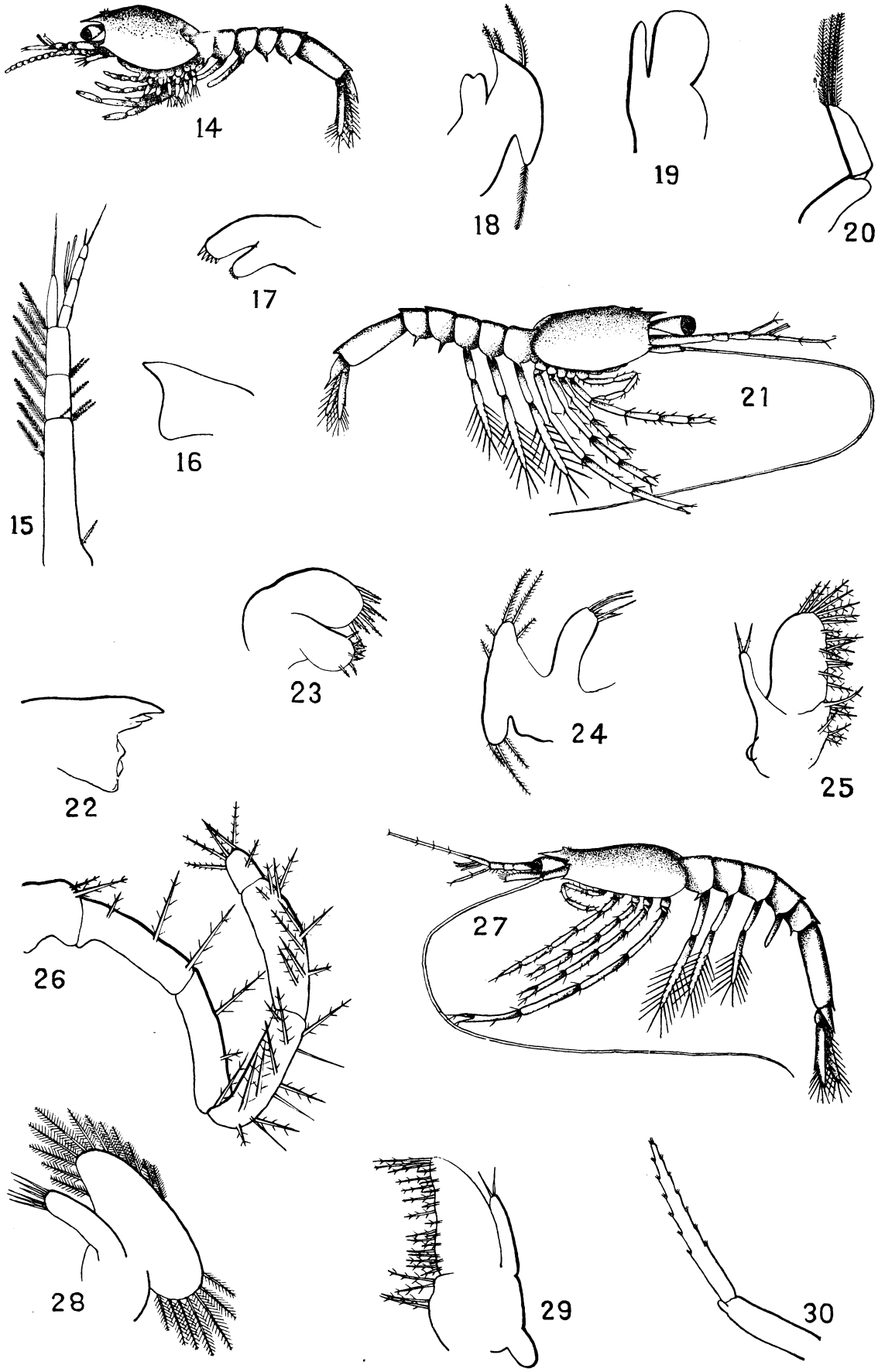


ACETES ERYTHRAEUS.

PLATE II.

ACETES ERYTHRAEUS.

Fig. 14. Mysis stage. × 20
„ 15. Antennule of mysis stage. × 150
„ 16. Mandible do. × 150
„ 17. First maxilla do. × 150
„ 18. Second maxilla do. × 150
„ 19. First maxillipede do. × 150
„ 20. Fourth thoracic leg do. × 150
„ 21. First mastigopus stage. × 20
„ 22. Mandible of first mastigopus stage. × 150
Fig. 23. First maxilla of first mastigopus stage. × 150
„ 24. Second maxilla do. × 150
„ 25. First maxillipede do. × 150
„ 26. Second maxillipede do. × 150
„ 27. Second mastigopus stage. × 15
„ 28. Second maxilla of second mastigopus stage. × 150
„ 29. First maxillipede do. × 150
„ 30. Third pleopod do. × 150



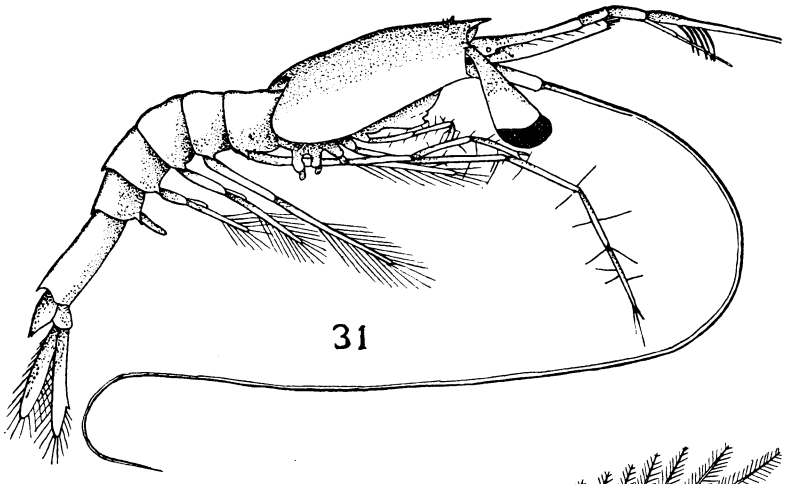
ACETES ERYTHRAEUS.

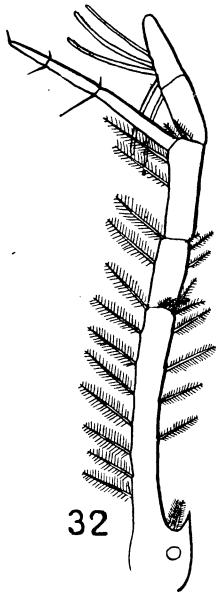
PLATE III.

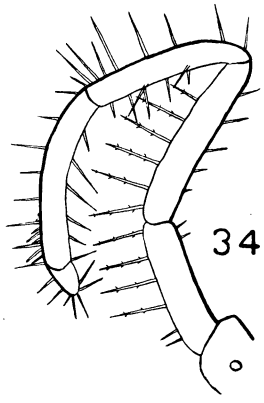
ACETES ERYTHRAEUS.

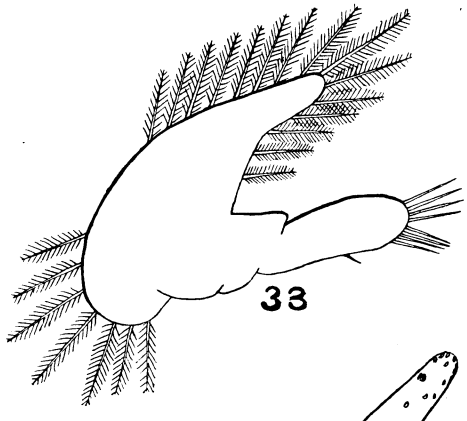
Fig. 31. Third mastigopus stage. × 16
„ 32. Antennule of third mastigopus stage. × 10
„ 33. Second maxilla do. × 150
„ 34. Second maxillipede do. × 32
„ 35. Clasping organ of lower antennular flagellum of adult (male). × 65

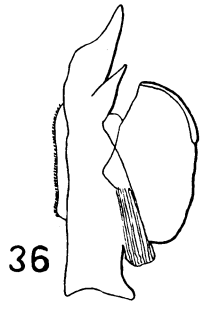
Fig. 36. Petasma of adult (male). × 32
„ 37. Capitulum and processus ventralis of petasma × 150
„ 38. Anterior part of adult (female). × 8
„ 39. Genital area (female). × 32
„ 40. Uropods of adult. × 8

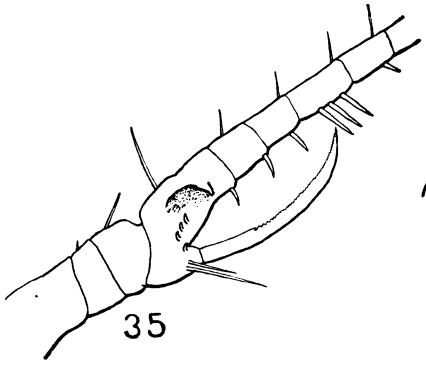


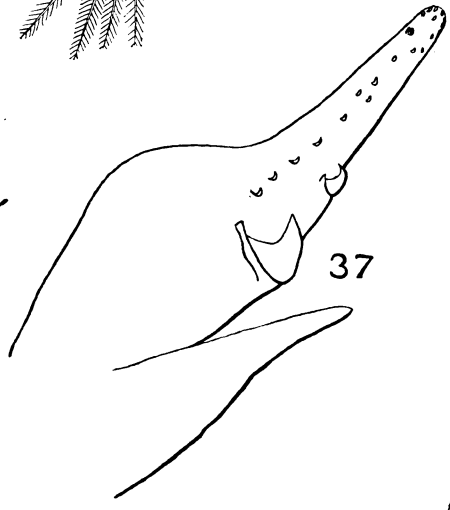


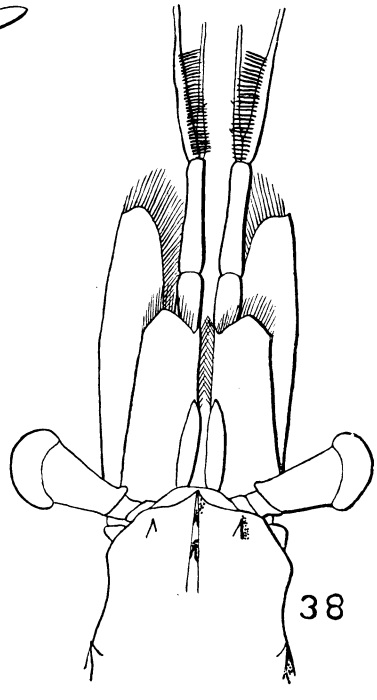


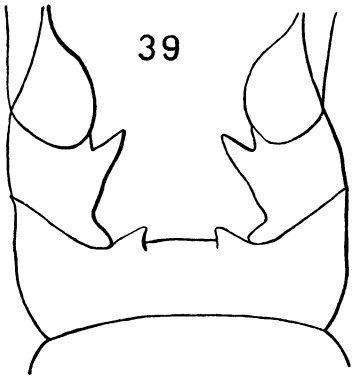


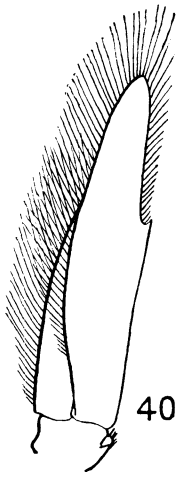










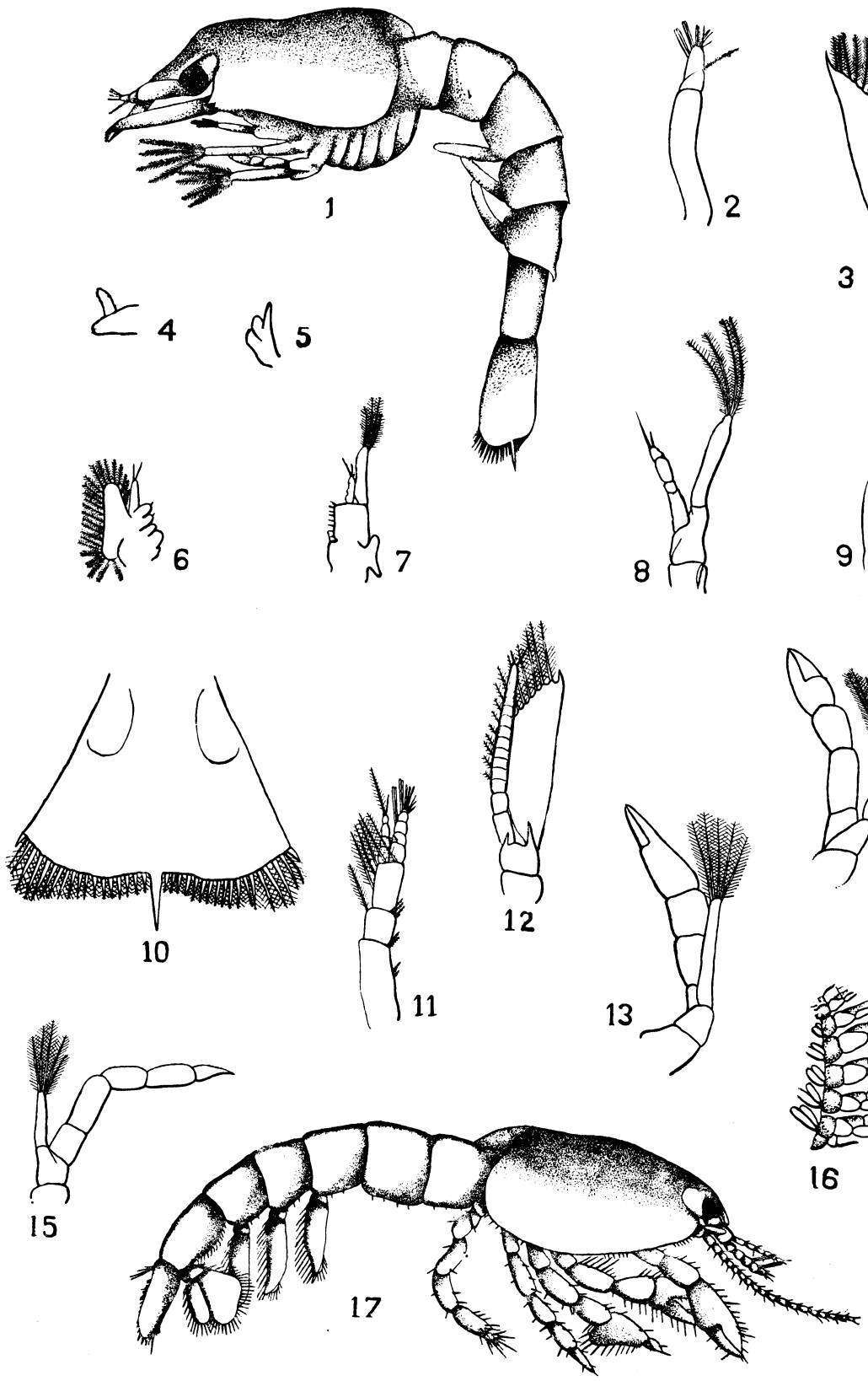


ACETES ERYTHRAEUS.

PLATE IV.

CALLIANASSA SP.

Fig. 1. First stage (entire animal). × 16
„ 2. Antennule of first stage. × 32
„ 3. Antenna do. × 32
„ 4. Mandible do. × 32
„ 5. First maxilla do. × 32
„ 6. Second maxilla do. × 32
„ 7. First maxillipede do. × 32
„ 8. Second do. do. × 32
„ 9. Pleopod of first stage × 32
Fig. 10. Telson of first stage. × 32
„ 11. Antennule of second stage. × 32
„ 12. Antenna do. × 32
„ 13. First thoracic leg do. × 32
„ 14. Second do. do. × 32
„ 15. Fourth do. do. × 32
„ 16. Arrangement of do. gills × 8
„ 17. First post-larval stage. × 16



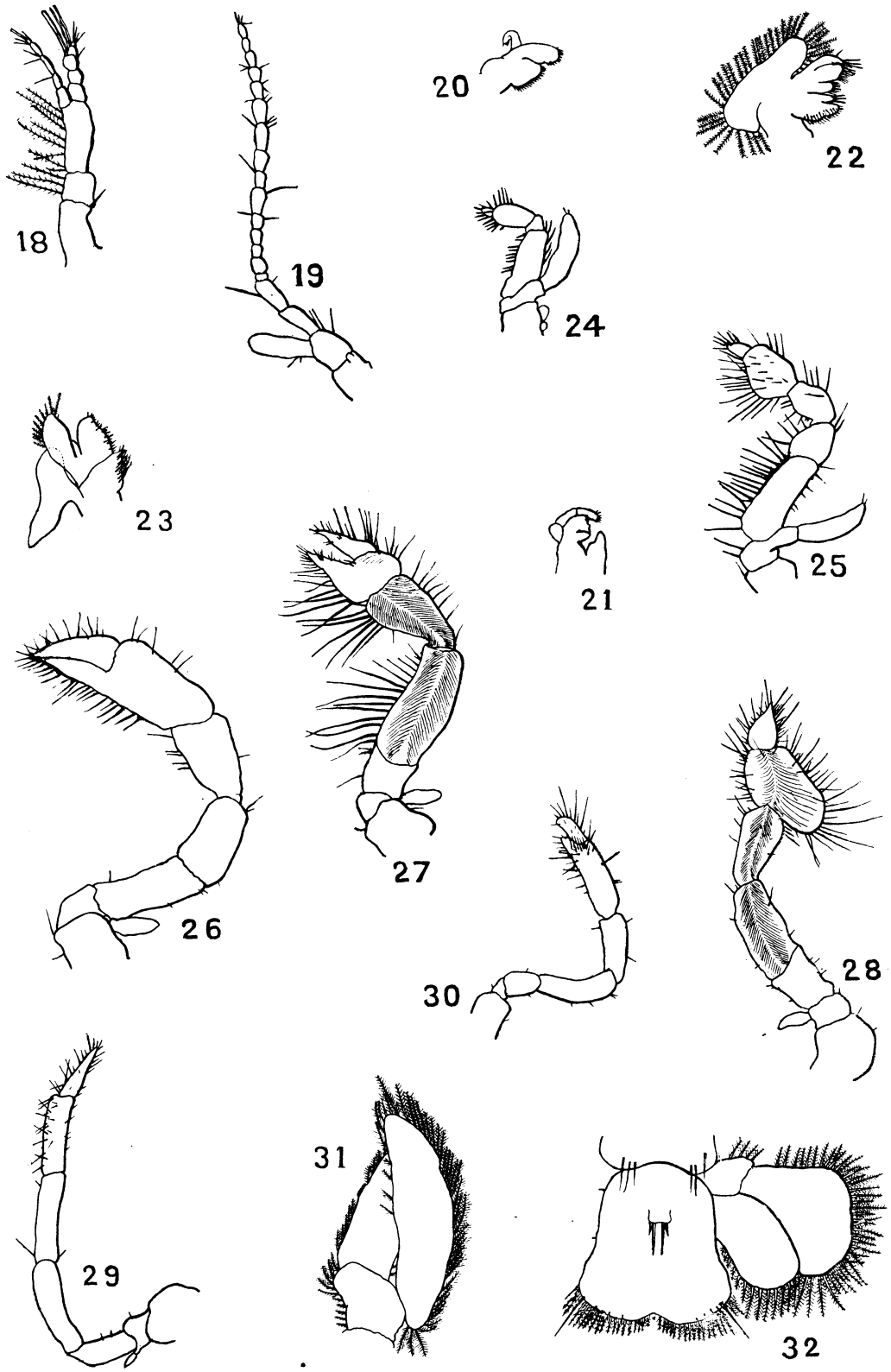
CALLIANASSA SP.

PLATE V.

CALLIANASSA SP.

Fig. 18. Antennule of first post-larval stage × 32
„ 19. Antenna do. × 32
„ 20. Mandible do. × 32
„ 21. First maxilla do. × 32
„ 22. Second maxilla do. × 32
„ 23. First maxillipede do. × 32
„ 24. Second maxillipede do. × 32

Fig. 25. Third maxillipede of first post-larval stage × 32
„ 26. First thoracic leg do. × 32
„ 27. Second thoracic leg do. × 32
„ 28. Third do. do. × 32
„ 29. Fourth do. do. × 32
„ 30. Fifth do. do. × 32
„ 31. Pleopod do. do. × 32
„ 32. Uropods and telson do. × 32



CALLIANASSA SP.

PLATE VI.

UPOGEBINAE.

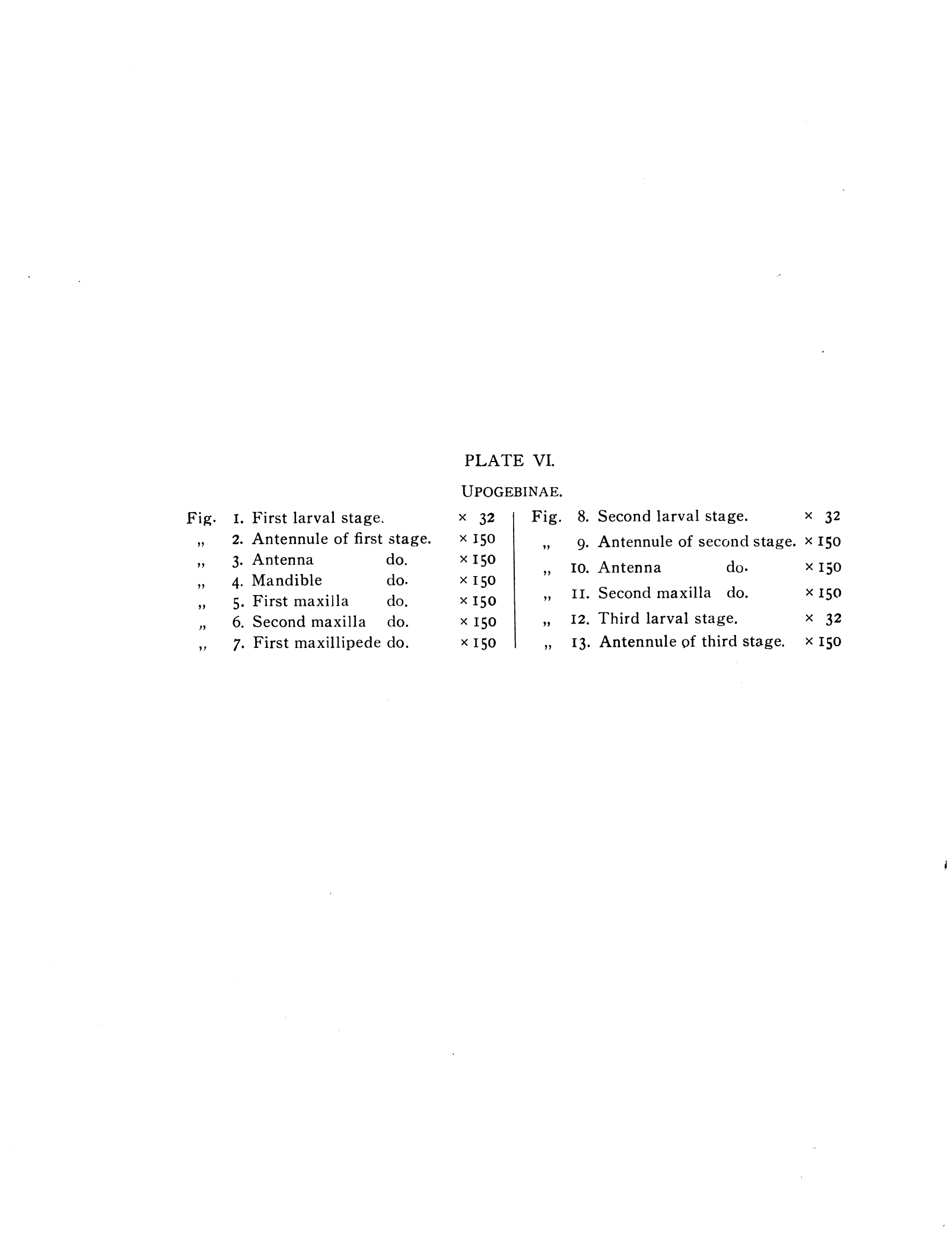
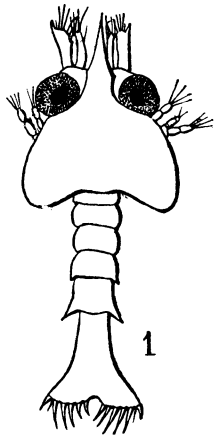
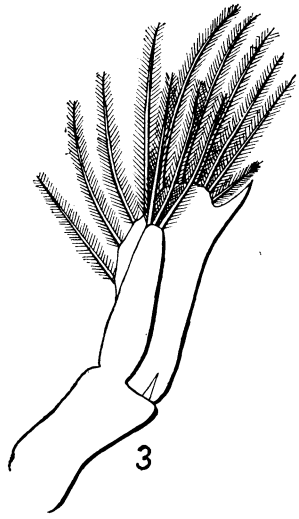
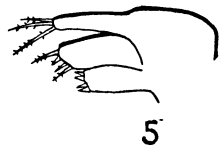
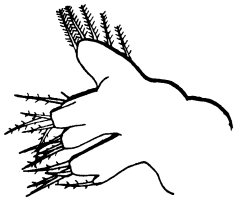


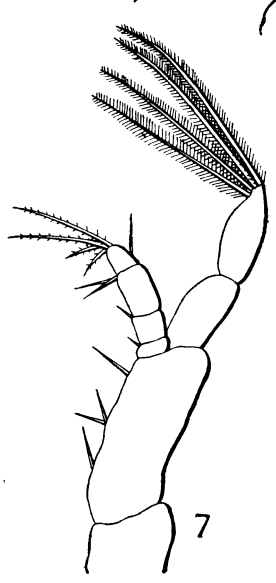
Fig. 1. First larval stage. × 32
„ 2. Antennule of first stage. × 150
„ 3. Antenna do. × 150
„ 4. Mandible do. × 150
„ 5. First maxilla do. × 150
„ 6. Second maxilla do. × 150
„ 7. First maxillipede do. × 150
Fig. 8. Second larval stage. × 32
„ 9. Antennule of second stage. × 150
„ 10. Antenna do. × 150
„ 11. Second maxilla do. × 150
„ 12. Third larval stage. × 32
„ 13. Antennule of third stage. × 150

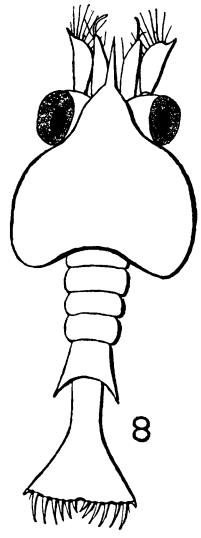


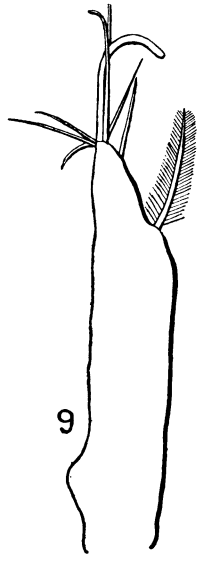


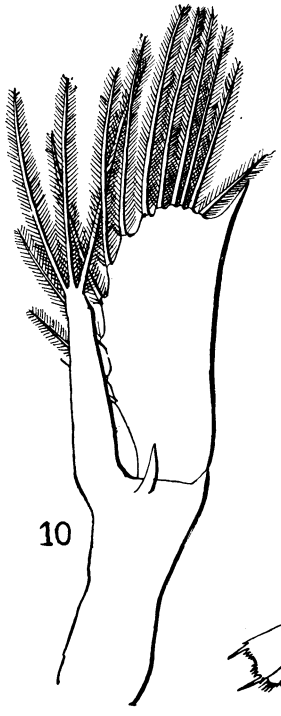


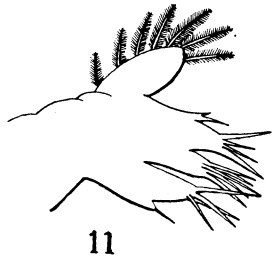


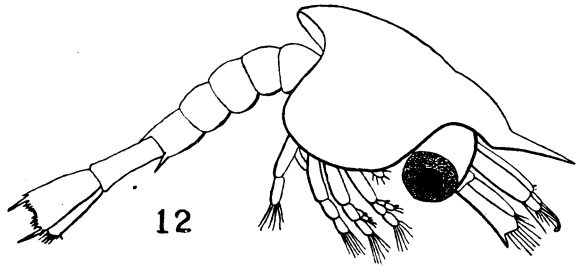


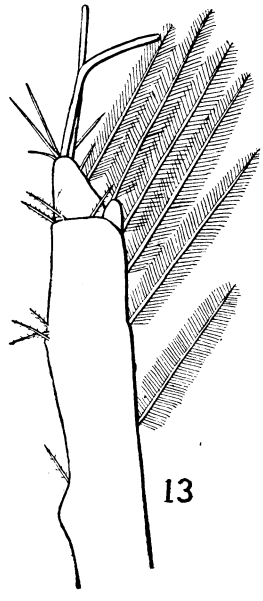










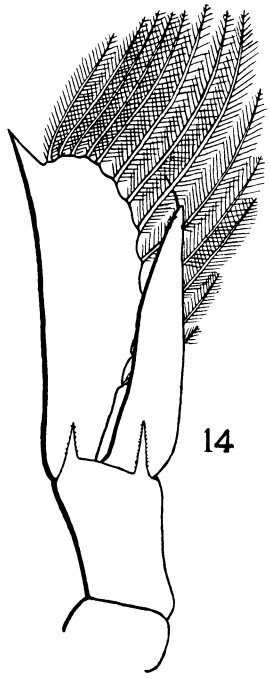


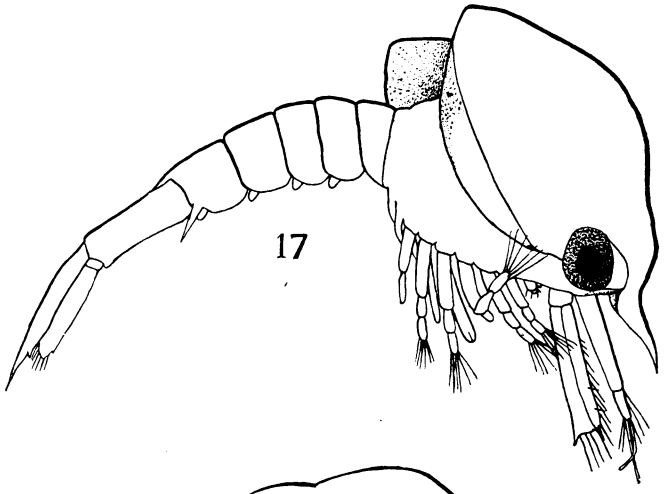
UPOGEBINAE.

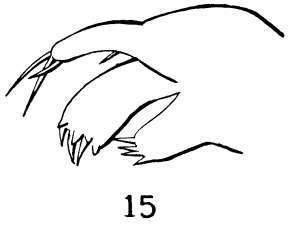
PLATE VII.

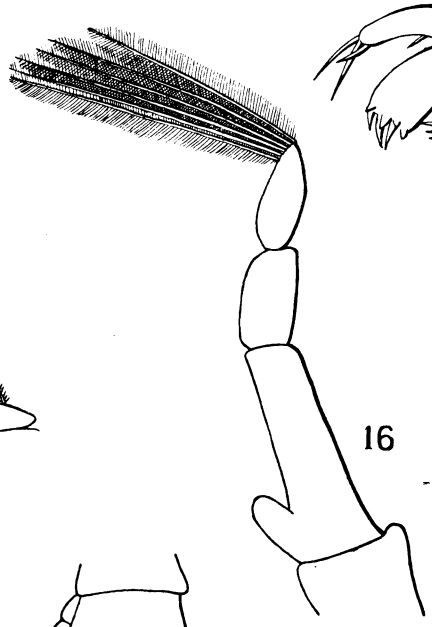
UPOGEBINAE.

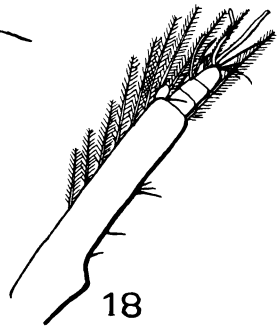
Fig. 14. Antenna of third stage. × 150
„ 15. First maxilla do. × 150
„ 16. Third maxillipede do. × 150
„ 17. Fourth larval stage. × 32
„ 18. Antennule of fourth stage. × 15
„ 19. First maxilla do. × 150
Fig. 20. Second maxilla of fourth stage. × 150
„ 21. Uropods and telson do. × 65
„ 22. Fifth (last) larval stage. × 150
„ 23. Telson and uropods of fifth stage. × 65

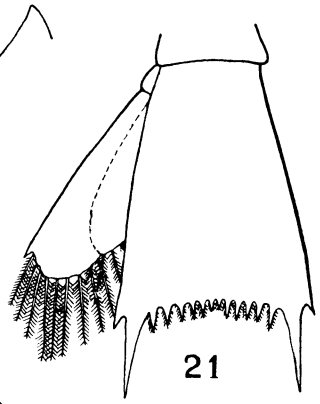


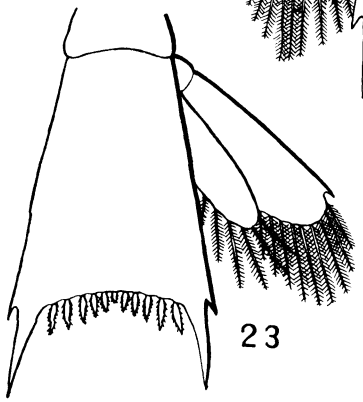


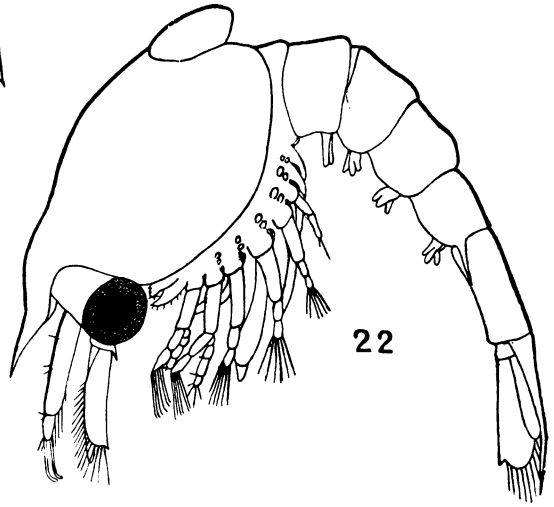












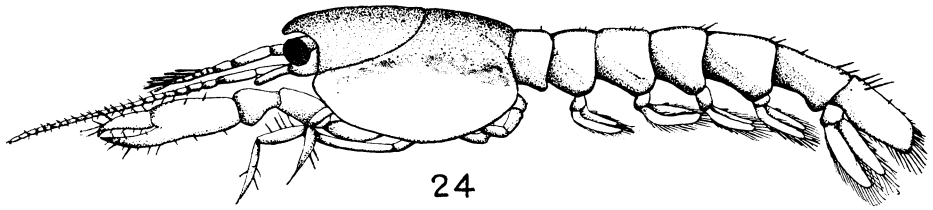
UPOGEBINAE.

PLATE VIII.

UPOGEBINAE.

Fig. 24. First post-larval stage. × 16
„ 25. Antennule of post-larval stage. × 62
„ 26. Mandible do. × 150
„ 27. First maxilla do. × 150
„ 28. Second maxilla do. × 65
„ 29. First maxillipede do. × 65
„ 30. Second maxillipede do. × 65
„ 31. Third maxillipede do. × 65

Fig. 32. First thoracic leg of post-larval stage (left terminal portion). × 32
„ 33. First thoracic leg of post-larval stage (right terminal portion). × 32
„ 34. Second leg of do. × 32
„ 35. Pleopod do. × 150
„ 36. Telson and uropods do. × 32



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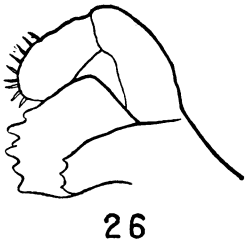

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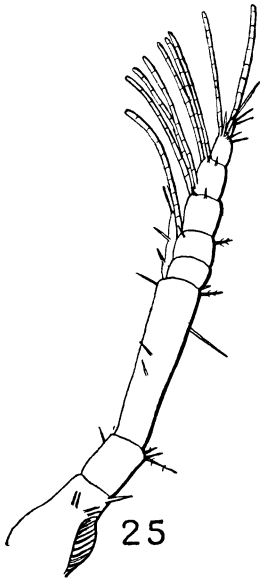

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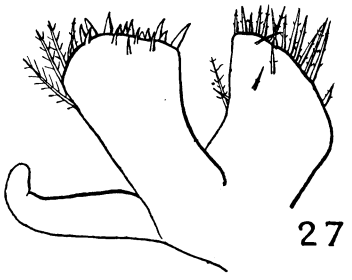

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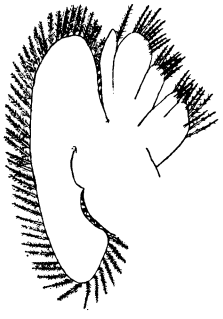

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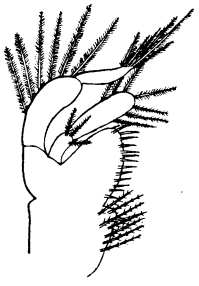

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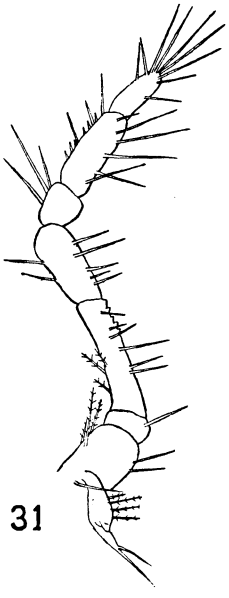

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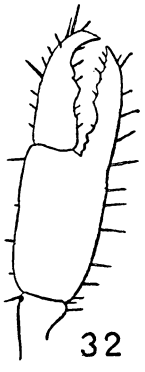

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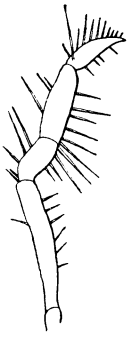

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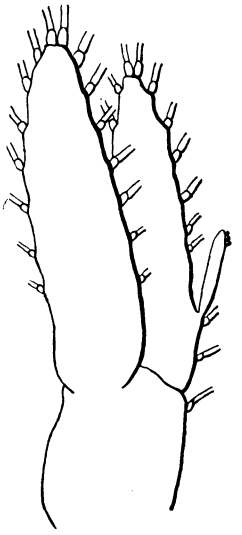

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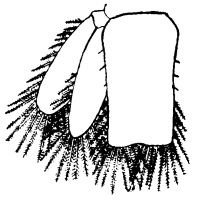

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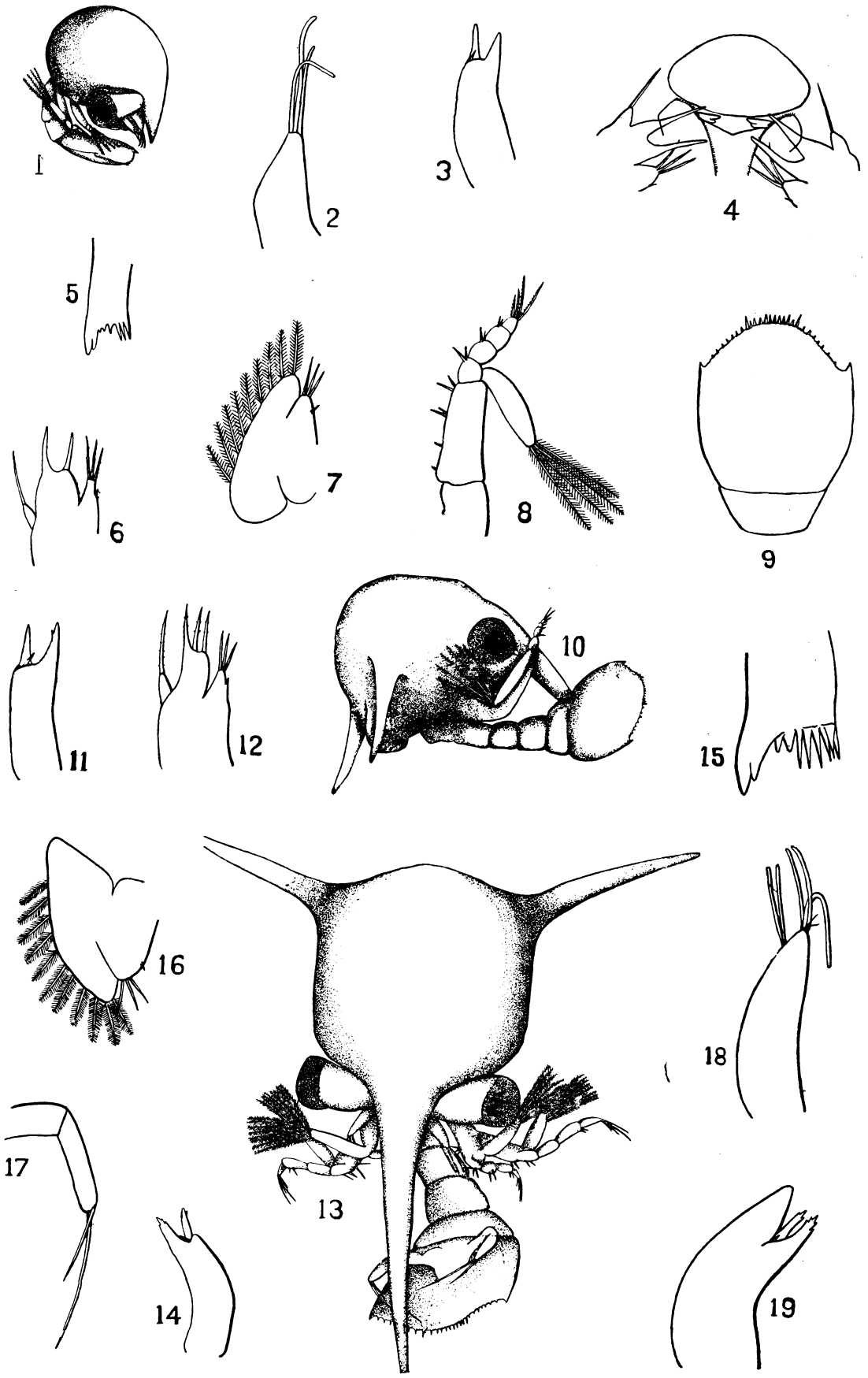
UPOGEBINAE.

PLATE IX.

HIPPA ASIATICA.

Fig. 1 First larval stage. × 32
„ 2. Antennule of first stage. × 65
„ 3. Antenna do. × 65
„ 4. Labrum and labium do. × 150
„ 5. Mandible do. × 150
„ 6. First maxilla do. × 65
„ 7. Second maxilla do. × 65
„ 8. First maxillipede do. × 32
„ 9. Telson do. × 65
„ 10. Second larval stage. × 32
Fig. 11. Antenna of second stage. × 65
„ 12. First maxilla do. × 65
„ 13. Third larval stage. × 32
„ 14. Antenna of third larval stage. × 65
„ 15. Mandible do.
„ 16. Second maxilla do. × 65
„ 17. Uropods do. × 65
„ 18. Antennule of fourth stage. × 65
„ 19. Antenna do. × 65

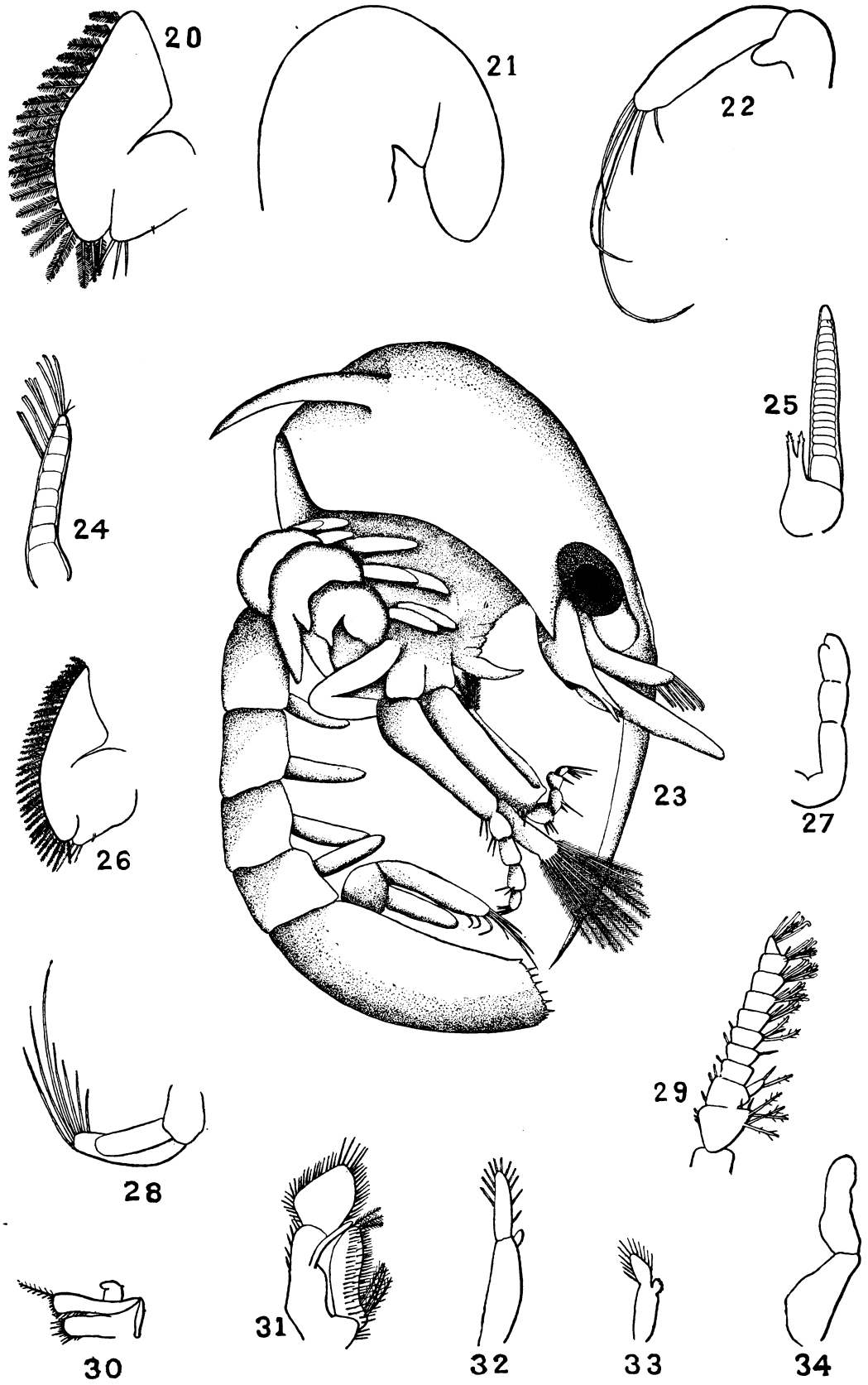


HIPPA ASIATICA.

PLATE X.

HIPPA ASIATICA.

Fig. 20. Second maxilla of fourth stage. × 65
„ 21. First thoracic leg do. × 150
„ 22. Uropods do. × 65
„ 23. Fifth (last) larval stage. × 32
„ 24. Antennule of fifth stage. × 32
„ 25. Antenna do. × 32
„ 26. Second maxilla do. × 32
„ 27. Last thoracic leg do. × 32
Fig. 28. Uropods of fifth stage. × 32
„ 29. Antennule of first post-larval stage. × 32
„ 30. First maxilla of first post-larval stage. × 32
„ 31. First maxillipede do. × 32
„ 32. Pleopod of first do. × 32
„ 33. Do. second do. × 32
„ 34. Do. third do. × 150



HIPPA ASIATICA.

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Page numbers printed in Roman type refer to the main references (including all descriptive ones), those in italics to subsidiary ones.

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SAGITTA OF THE MADRAS COAST

BY

C. C. JOHN, M.A., D.Sc.

(Published—June 1933)

SAGITTA OF THE MADRAS COAST

By C. C. JOHN, M.A., D.Sc.

CONTENTS.

INTRODUCTION.

During the years 1930–1932 the Zoological Research Department of the Madras University collected some quantities of plankton from the Madras Coast, the greater part of which was worked out in the form of a "Preliminary Account of Madras Plankton" (K. Sankara Menon, 1931). The collection contained a fairly good quantity of *Sagitta*, which were identified as *S. bipunctata*. As I was interested in studying the distribution of the group I requested permission to examine the collection and my thanks are due to Mr. R. Gopala Ayyar, the honorary Director of the Zoological Research Laboratory for kindly giving me the necessary facilities for sorting out the *Sagitta*, which form the material for this little paper.

The *Sagitta* of the East Coast of India has never been identified before. The only reference to it is found in the Reports of the Siboga Expedition (Fowler, 1906). Though that expedition did not investigate the Bay of Bengal, in two of the charts on the distribution of the genus Fowler shows the occurrence of *S. enflata* and *S. subtilis*. Later when one of the officers of the Madras Fisheries Department proceeded to England, he took with him a few badly preserved specimens, which were doubtfully identified there as *S. bipunctata* and the account of the previous worker was probably based on that.

In the present paper five species *S. enflata*, *S. gardineri*, *S. neglecta*, *S. tenuis* and *S. robusta* have been identified, of which *S. enflata*, *S. gardineri* and *S. tenuis* occur abundantly. *S. neglecta* is very scarce and I have been able to obtain only a very few specimens from the entire collections. Considering the number of species obtained from the Maldive and Laccadive Islands by Doncaster (1902) it is possible that some more species may be obtained from the Bay of Bengal with better methods of collection.

Genus Sagitta.

S. enflata, Grassi, 1883.

S. flaccida, Conant, 1896.
S. brachycephala, Doncaster, 1902.
S. furcata, Michael, 1908.
S. enflata, Ritter Zahany, 1908 and 1909.

General appearance.—This species is characterised by the fact that the body is very transparent and tumid. Fins are barely visible except when viewed against a black

background. Head separated from the trunk by a pronounced constriction at the tail septum. Body widest at a point about 50 per cent from the tip of the head. Anterior fin shorter than the posterior fin and is situated far behind the ventral ganglion, the distance between the ganglion and the fin being about 30 per cent of the total length. The posterior fin longer and broader than the anterior fin. It is almost triangular in form and the position of greatest width is uniformly opposite the tail septum. Interval between anterior and posterior fin usually about 8–10 per cent of the total length.

Seminal vesicles are situated at the anterior end of the tail fin and have a spherical form. The body-wall surrounding the seminal vesicle is thickened into an opaque patch which extends to the tip of the tail. (Ref. fig. 1, sem. ves.).

Measurements—

Length	... ...	12–13 mm.	
Width	... ...	7–11 per cent.	
Length of tail	...	15–20	,,
Length of anterior fin.		10–11	,,
Anterior fin to ventral ganglion.		30–38	,,
Anterior fin to posterior fin.		9–10 per cent.	
Length of posterior fin.		14–15	,,
Distance between genital openings.		8	,,
Anterior teeth	... ...	5–9	
Posterior teeth	... ...	7–12	
Prehensile spines	...	8	

The number of teeth and prehensile spines (seizing jaws) do not have any systematic value, as will be shown later; they are given here only to make the list complete.

All percentages calculated in relation to total length.

In comparison with Michael's San Diego material the only noticeable difference is with regard to total length. He finds the total length to be 15–21 mm. (Michael, 1911), while in the Madras specimens the variation is only from 12–13 mm.

S. gardineri, Doncaster, 1902.

This species was first recorded from the Maldive and Laccadive Islands by Doncaster but Michael (1911) regarded it as a synonymy of *S. enflata*. Though in general appearance it resembles *S. enflata* more closely than any other species, the differences between the two forms are strong enough to justify the position of *S. gardineri* as a distinct species.

General appearance.—Body thick, transparent and tumid, head broad and short, separated from the trunk by a distinct neck. Body widest at a point about 40 per cent of the total length from the tip of the head. Tail marked off from the trunk by a constriction at the tail septum, but the construction not so pronounced as in *S. enflata*. Anterior fin longer than the posterior fin but never extends to the ventral ganglion. Distance from fin to ventral ganglion about 12–14 per cent. Position of greatest width always near the posterior end of the fin. Fin triangular with its apex directed posteriorly. In *S. enflata* the

anterior fin is shorter than the posterior and the distance from the fin to the ventral ganglion varies from 17–26 per cent in the San Diego material. The shape of the fin is also different in the two species.

Posterior fin shorter but broader than the anterior fin, always less than 50 per cent behind the tail septum. Position of greatest width uniformly opposite the tail septum. Interval between anterior and posterior fin usually 6–7 per cent.

Seminal vesicles are spherical and are placed at the front end of the tail fin, as in *S. enflata* but the chief difference between the two species is that while in *S. enflata* the distance between the external opening of the oviduct and the seminal vesicle is 8 per cent, in *S. gardineri* it is 12 per cent. Whatever be the similarity between two forms the chief factor for including them in the same species must depend on a consideration whether sperm-transference is possible between the individuals of the two forms. This will be possible only if the percentage distance between the two genital openings is the same in both the forms. When this percentage differs sexual union is impossible even when two individuals, belonging to the different forms happen to be of the same length, because the seminal vesicle of the one will not touch the oviductal opening of the other or *vice versa*. This gives sufficient reason for separating *S. gardineri* from *S. enflata* and regarding it as a distinct species.

Measurements—

Total length	...	11–12·5 mm.	
Width	... ...	7–9 per cent.	
Length of tail	...	18–20	„
Length of anterior fin.		19–21	„
Anterior fin to ventral ganglion.		12–14	„
Anterior fin to posterior fin.		6–7 per cent.	
Length of posterior fin.		15–18	„
Distance between genital openings.		12	„
Anterior teeth ...	..	7–10	
osterior teeth ...	...	10–14	
Prehensile spines	...	8–10	

All percentages calculated in relation to total length from tip of head to tip of tail.

S. neglecta, Aida, 1897.

General appearance.—This species can be easily distinguished by its slender pin-shaped, opaque body and comparatively large head. The head is broader than the trunk, which gradually tapers to a point at the tip of the tail. The tail segment is slightly less opaque than the trunk and the seminal vesicles do not present such decided contrast as in the other species. The fins are very transparent and are visible only against a black background. A neck is present but it is made less conspicuous by a collarette which extends nearly half-way towards the ventral ganglion. Though the trunk is nearly of uniform width it is slightly wider at a point near the anterior end of the ovaries. The trunk continues imperceptibly as the tail without any construction at the

tail septum. Anterior fin narrower than the posterior fin, extends to the posterior end of the ventral ganglion and is only slightly shorter than the posterior fin. Position of greatest width situated near the posterior end of the fin from where it tapers gradually towards its anterior end.

Posterior fin half elliptical and always more than 50 per cent behind tail septum, and the position of greatest width also situated well behind the tail septum. The ovaries are comparatively large and extend to a point slightly in front of the hind end of the anterior fin. In mature specimens each ovary is filled with 12–14 large eggs. The seminal vesicles, which are not very conspicuous structures, are placed near, but not quite close to the hind end of the posterior fins.

Measurements—

Total length	...	7–10 mm.	
Width ...	...	4–6 per cent.	
Length of tail	...	27–30	„
Length of anterior fin.		18–20	„
Anterior fin to posterior fin.		8–10	„
Length of posterior fin.		22–26 per cent.	
Distance between genital openings.		17	„
Anterior teeth ...	...	4–5	
Posterior teeth ...	...	10–12	
Prehensile spines	...	8	

All percentages calculated in relation to total length from tip of head to tip of tail fin.

S. tenuis, Conant, 1896.

General appearance.—This is the smallest species of *Sagitta* known, a fully grown adult measuring only 5–5·5 mm. The body is very slender and opaque and is widest at about the middle, from where it tapers gradually towards both ends. Neck not conspicuous owing to the presence of a small collarette, body opaque, with strong trunk muscles. A construction at the tail septum separates the trunk from the tail. This construction is very pronounced owing to the presence of a wart-like prominence in front of the tail septum, through which the oviduct opens externally (Ref. fig. 4, ext. op.). This wart makes the external opening of the oviduct protrude slightly beyond the general surface of the body-wall.

Anterior fin shorter and narrower than the posterior fin, extends to the ventral ganglion and position of greatest width is situated near the posterior end, from where the fin tapers gradually towards the anterior end. Posterior fin almost half elliptical, less than 50 per cent in front of tail septum and position of greatest width situated well behind the tail septum.

Ovary is relatively large and conspicuous and extends nearly to the middle of the anterior fin. In mature specimens each ovary is filled with 14–15 large eggs. Seminal vesicle is small with pointed apex. It is situated near the hind end of the posterior fin, but not actually touching the latter.

Measurements—

Total length	... 5-5·5 mm.	Length of posterior fin.	24–25 per cent.
Length of tail segment.	25–28 per cent.	Distance between genital openings.	20 ,,
Length of anterior fin.	12–14 ,,	Anterior teeth	... 5–7
Anterior fin to posterior fin.	10–12 ,,	Posterior teeth	... 7–8
		Prehensile spines	... 8

All percentages calculated in relation to total length.

S. robusta, Doncaster, 1902.

General appearance.—Body opaque, slender and pin-shaped and specimens preserved in Formalin show a slightly brownish tint. Trunk muscles strong and thick. Position of greatest width situated at about 60 per cent of the total length from tip of head. From this point the body tapers gradually towards the head and more abruptly towards the tail. Tail marked off from the trunk by a slight construction at the tail segment. Neck distinct but made less conspicuous by the presence of a collarette. Head broad and thick. The shape of the head varies according to the condition of the prehensile spines. When the latter are exposed the hood is drawn backwards and the head becomes narrower (Fig. 5b), but when the spines are closed the hood is drawn over the greater part of the head and the head broadens posteriorly.

Anterior fin longer but narrower than posterior fin, very transparent and often damaged in the preserved condition. It extends very nearly to the posterior end of the ventral ganglion, the distance between the fin and the ganglion being always less than 5 per cent of the total length. Posterior fin almost triangular, with more than 60 per cent behind the tail septum and the position of greatest width situated at a point well behind the tail septum.

The oviduct opens externally through a wart-like prominence situated just in front of the tail septum as in *S. tenuis*. The seminal vesicles are placed close to the hind end of the posterior fin.

Measurements—

Total length	... 10–12 mm.	Anterior fin to posterior fin.	7–8 per cent.
Length of tail segment.	25–27 per cent.	Length of posterior fin.	18–20 ,,
Length of anterior fin.	27–29 ,,	Distance between genital openings.	13 ,,
Anterior fin to ventral ganglion.	4 ,,	Anterior teeth ...	... 8–9
		Posterior teeth ...	... 10–12
		Prehensile spines	... 6

The tips of prehensile spines are slightly curved like hooks (Ref. fig. 5b). One difference between the present collection and those described by Doncaster (1902) is with regard to the length of the anterior fin. According to him the anterior fins are only as long as the posterior fins. This point is not definitely cleared by Michael (1911) who has only given the length of the anterior fin but not of the posterior fin. In the present collection the anterior fins are decidedly longer than the posterior. This difference is either a local variation such as is commonly met within the group, or due to the fact that the anterior fin is very often damaged. In about fifty specimens which I examined I was able to get only seven in which the fins were in tact.

THE IDENTIFICATION OF THE SPECIES OF SAGITTA.

The characters which are used to distinguish the species of *Sagitta* are so variable that examples obtained from the same locality differ considerably from one another and it is sometimes a matter of difficulty to determine the species with any certainty. Hitherto identification had been based on (1) the percentage measurements of the trunk and tail, (2) the position and relative lengths of the two pairs of lateral fins, (3) the number of anterior and posterior teeth and prehensile spines (seizing jaws), (4) the structure of the prehensile spines, (5) the position of the anterior fins in relation to the ventral ganglion, (6) the extent of the posterior fin in front of the tail septum, (7) the presence or absence of collarettes and (8) the general nature of the body and the average total length of the adult specimens. All these characters have not been described by the different authors who have worked on *Sagitta*. Each author chose those characters which he thought most suitable and this resulted in the considerable increase of the number of species, till eventually Michael (1911) formulated the set of characters given above, but as shall be shown in the following account some of the characters laid down by him do not have any real systematic value, and are consequently quite unimportant.

The number of prehensile spines, anterior teeth and posterior teeth are never constant in the different examples of the same species collected at any particular locality. This has been explained by the fact that their number increases with the age of the specimens (John 1931). Further the prehensile spines show almost the same numerical variation in most species. For example in *S. enflata* there are 8–9 prehensile spines, in *S. hexaptera*, 6–9, in *S. lyra* 4–8, *S. serratodentata* 6–8, *S. bipunctata* 8, *S. planktonis* 8–9, *S. neglecta* 7–8, *S. hispida* 8–9, and *S. tenuis* 8. It will be seen that in all the species mentioned above it is possible to get specimens which have eight prehensile spines. Therefore it is evident that the number of prehensile spines as a character for identification of the species is very weak indeed. In the nature of the spines the only distinguishing feature is found in *S. serratodentata* where the inner edge is serrated.

The curvature of the spines is a very satisfactory character, but unfortunately only very few authors have described it and the species in which this has been observed are so few compared with the total number of species that it cannot be used as a key for identification unless all the remaining species are worked out afresh on this basis, but

considering that other characters are quite suitable and easily determined it is not worth while for the student of systematic zoology to make any such attempt. Specific characters which are of real value in the identification of species must be as far as possible such that they could be easily determined without the aid of any special technique. The calculation of the curvature of the prehensile spines and the observation of the structure of the vestibular ridge involve rather elaborate process and careful calculation. Fowler deliberately omits them because the strain was to much for his eyes. It is therefore proposed to give a set of characters which can be easily observed under any ordinary Cinocular microscope or calculated without undue trouble.

1. *The general appearance of the body.*—Each species of *Sagitta* has its own characteristic appearance. For instance *S. enflata* is very transparent and the trunk though tumid still retains its form very well. The trunk of *S. hexaptera* is also tumid but the body is not quite so transparent and the muscles of the trunk are stronger than those of *S. enflata* but the body does not always retain its form. *S. gardineri* is similar to *S. enflata* yet the two can be easily distinguished by the differences in the position of the lateral fins. *S. lyra* is nearly transparent on a black background but the intestine is more opaque and the body is usually of a grayish or slate colour *S. bipunctata* has a rigid body which retains its form very well. The three species, *S. serratodentata*, *S. neglecta* and *S. tenuis* have a pin-shaped body but these can be distinguished from each other by the fact that the inner edge of the prehensile spines in *S. serratodentata* is serrated, the head of *S. neglecta* is comparatively large and *S. tenuis* is usually very short. In these three species the body is broadest at the region of the neck from where it tapers to a point at the tip of the tail. In *S. bipunctata*, *S. enflata*, *S. lyra*, *S. hexaptera*, *S. gardineri* and *S. planktonis* the broadest point is situated somewhere about the middle of the body from where it tapers gradually towards the head and more abruptly towards the tail. The position of greatest width varies in different species. It is situated at about 40–45 per cent of the total length from the tip of the head in *S. hexaptera*, 50–60 per cent in *S. bipunctata* and 40–60 per cent in *S. planktonis*. In some species, e.g., *S. serratodentata*, *S. tenuis*, *S. robusta*, *S. neglecta* and *S. planktonis* the tail segment continues uninterrupted from the trunk, but in *S. enflata*, *S. gardineri*, *S. hexaptera*, *S. bipunctata* and *S. elegans* the tail septum is marked off by a constriction, which varies in nature in the different species. It is most pronounced in *S. enflata* and least in *S. bipunctata*.

2. *The anterior fin.*—The length and width of the anterior fin in relation to the posterior fin and its position relative to the ventral ganglion, vary in different species. The anterior fin is invariably narrower and except in *S. robusta*, *S. whartoni* and *S. lyra* shorter than the posterior fin. In *S. lyra*, *S. serratodentata*, *S. planktonis* and *S. neglecta* it extends to the ventral ganglion. *S. robusta* can be distinguished from *S. lyra* and *S. whartoni* by the fact that in the latter examples the anterior fin is confluent with the posterior. The shape of the anterior fin also varies in the different species. In *S. bipunctata*, *S. planktonis* and *S. neglecta* it is triangular. In *S. hexaptera* it is half elliptical while in *S. serratodentata* it is almost triangular with the broadest point situated near the posterior end.

3. *Posterior fin.*—The shape of the posterior fin and its relation to the tail septum varies in different species. Except in the three species *S. lyra, S. whartoni* and *S. robusta* the posterior fin is broader and longer than the anterior fin. The posterior fin is situated in such a way that it is partly in front and partly behind the tail septum. In *S. enflata, S. gardineri, S. hexaptera, S. bipunctata, S. planktonis* and *S. elegans* more than 50 per cent of the fin is in front of the tail septum, while in *S. lyra, S. neglecta, S. hispida, S. robusta* and *S. tenuis* more than 50 per cent of the fin is behind the tail septum. In *S. serrotodentata* alone the length of the posterior fin in front of the tail septum varies from 41–62 per cent so that in some specimens more than 50 per cent and in others less than 50 per cent of the fin is in front of the tail septum. The shape of the fin is almost triangular or semi-elliptical. In those species in which the fin is almost triangular the position of greatest width varies in different species. In *S. enflata, S. gardineri, S. hexaptera, S. lyra* and *S. whartoni* the position of greatest width is uniformly opposite the tail septum. In *S. robusta, S. neglecta, S. serratodentata* and *S. elegans* the position of greatest width is behind the tail septum, while in *S. planktonis* and *S. arctica* it is front of the tail septum.

4. *The interval between the anterior and posterior fins.*—In *S. lyra* and *S. whartoni* the two fins are close together and the presence of a narrow fin bridge renders the two fins confluent, but in other species the two fins are separate and the length of the interval between the two fins in relation to the total ength of the animal varies from 4–16 per cent in the different species.

5. *The position of the seminal vesicles.*—The seminal vesicles are placed in the region between the posterior fin and the tail fin. In some species such as *S. bipunctata* and *S. serratodentata* the interval between the posterior fin and the tail fin is very short so that the seminal vesicles almost completely fill this space, but in others the distance between the two fins is greater and the seminal vesicles are placed either close to the posterior fin or the tail fin. The former condition is found in *S. elegans, S. lyra, S. hispida* and *S. robusta.* In a few others, e.g., *S. neglecta* and *S. tenuis* though the seminal vesicles are situated close to the posterior fin the end of the fin does not actually reach the seminal vesicles. The seminal vesicles occur close to the tail fin in *S. enflata, S. gardineri, S. planktonis* and *S. sibogae* (?).

6. *The percentage distance between the seminal vesicles and the opening of the oviduct.*—In Chaetognatha sperm transference is reciprocal. During this process two individuals come together with their head pointing towards opposite directions and in such a way that the seminal vesicle of the one touches the oviductal opening of the other and *vice versa.* For effecting sperm-transference it is therefore essential that the distance between the external openings of the two organs must show a constant relation to the total length. The total length of different individuals of the same species shows certain amount of variation and so sperm-transference is possible only between individuals of the same length. From what is known of the distribution of the group it is evident that the total

length of any given species of *Sagitta* varies with the temperature of the locality from which the specimens have been obtained. Specimens from colder regions are always longer and bigger than those obtained from warmer seas, similarly specimens recorded from abyssal regions are larger than the surface forms. For instance *S. hexaptera* ranges in distribution from 70° N. to 40° S. under conditions of temperature varying from 6° to 29°. Specimens of *S. hexaptera* obtained from the colder regions reach a length of about 70 mm., while those which approach the tropical seas are only 20–27 mm. in length. In specimens which are about 25 mm. long, such as those obtained from the Gulf of Naples, the distance between the external openings of the oviduct and the seminal vesicle is 3·2 mm. The increase in the total length of the specimens is followed by a corresponding increase of the interval between the genital openings so that in specimens which are about 70 mm. long the distance between the genital openings is 9·1 mm. Sperm transference is therefore not possible between individuals of different lengths, but as the increase in length is accompanied by a corresponding increase in the distance between the genital openings, the percentage distance between the genital openings, calculated in relation to the total length of the animal is always constant. In *S. hexaptera* the distance between the genital openings is 13 per cent, and it will therefore be seen that sperm transference in *S. hexaptera* is possible only between any two individuals which happen to be of the same length.

Sagitta shows coincident distribution in most places where it has been recorded. In the English Channel three species are usually found, in the San Diego region about seven species have been recorded, while the "Plankton Expedition" has been able to obtain about ten species at some of its stations in the Atlantic Ocean. The different species are found together, all having, so far as we know, similar habits. Geographical isolation or differences in breeding habits apparently do not exist, but still it does not seem probable that cross-breeding ever occurs. Even in closely allied species the distinctions are well marked, though within each species there is a certain degree of variation. From a study of the habits and structure of *Sagitta* the only factor which bars cross-breeding and mixture of the different species seems to be the percentage distance between the genital openings. This percentage is different in different species, so that sperm transference is impossible between individuals of different species even if they happen to be of the same length. In spite of coincident distribution and similarity of habits the various species have remained distinct through this factor and, as the accompanying table shows, this percentage is a very satisfactory character for identification when considered along with the total length of the specimens.

The percentage distance between genital openings has been determined in eight species, and in some cases a considerable number of specimens have been used for verifying the results. In none of the examples has the percentage been found to vary more than 0·9 and even this slight variation is probably due to errors in scale reading. In all cases the decimal figures have been counted as 1 when they were more than 0·5.

The percentage for the eight species are as follows :—

Name of species.	Percentage distance between genital openings.	Total length.
S. gardineri	12 %	10–13 mm.
S. enflata	8 %	12–21 ,,
S. serratodentata	18 %	12–17 ,,
S. hexaptera	13 %	27–70 ,,
S. neglecta	17 %	7–13 ,,
S. tenuis	20 %	5–5·5 ,,
S. elegans	11 %	21–23 ,,
S. robusta	13 %	5–6·6 ,,

In *S. robusta* and *S. hexaptera* the percentage distance between the genital openings is the same, but it will be noticed that while the maximum length of *S. robusta* is 5–6·6 mm., *S. hexaptera* measures 27–70 mm.

REFERENCES.

AIDA, T. Chaetognatha of the Misaki Harbour. *Annot. Zool., Japan*, 1897.

CONANT, S. F. Notes on the Chaetognaths. J. *Hopkins Univ. Circ.* 15; also in *Ann. Mag. Nat. Hist.* 1896.

DONCASTER, L. Chaetognatha, with a note on the Variation and Distribution of the group. *Fauna and Geography of the Maldive and Laccadive Archipelago*, 1912.

FOWLER, G. H. Chaetognatha of the Siboga Expedition, with a Discussion of the Synonymy and Distribution of the group. *Siboga Exped. Monogr., No.* 21, 1906.

GRASSI, B. I Chaetognati. *Faunau Flora des Golfes von Neapel, Monogr. V*, 1883.

JOHN, C. C. On the Anatomy of the Head of Sagitta. *Pro. Zool. Soc., pt.* 4, 1931.

MICHAEL, E. L. Notes on the Identification of Chaetognatha. *Biol. Bull.* 15, 1908.

——— Chaetognatha of the San Diego Region. *Univ. Calf. Pub. Zoology, Vol. VIII, No.* 3, 1911.

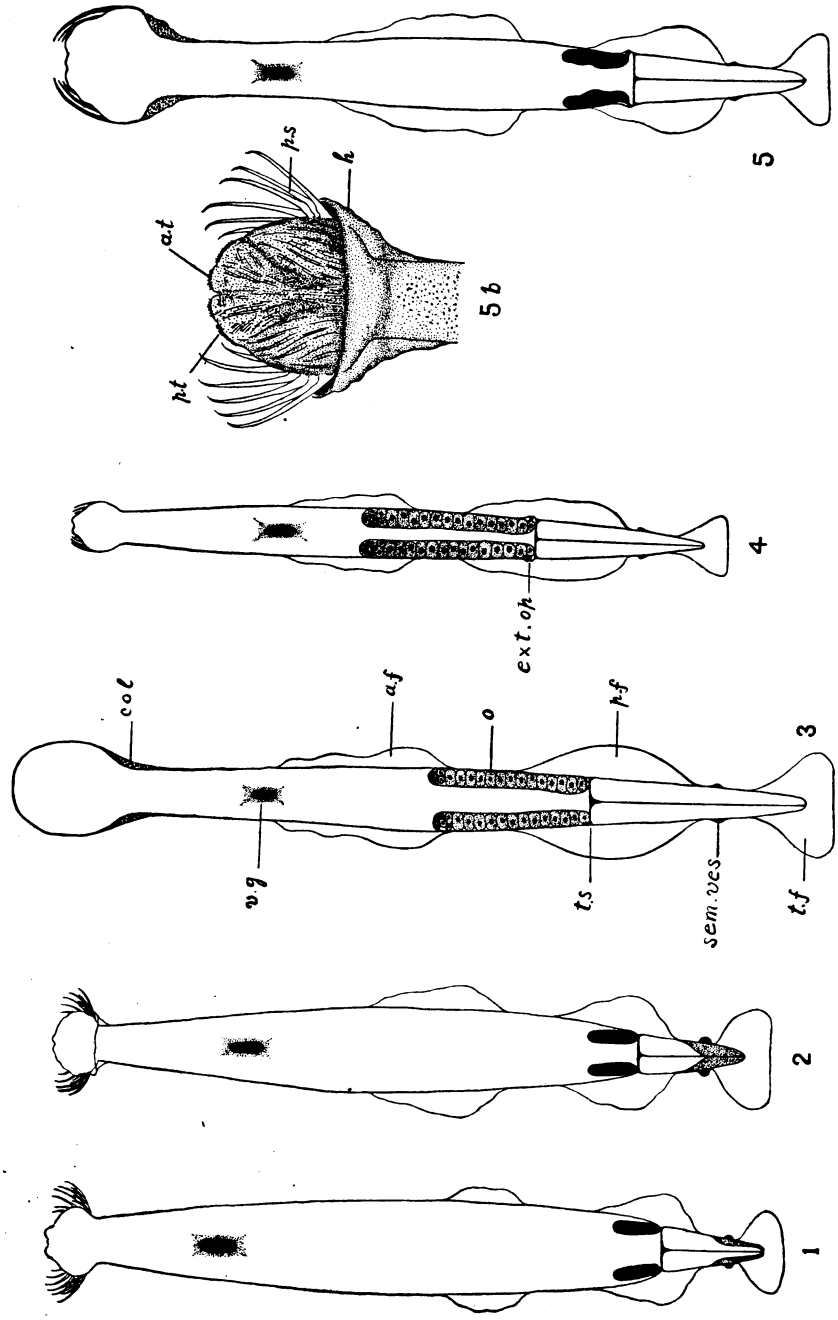
——— Report on the Chaetognatha of the 'Albatross' in Philippine Expedition, 1907–1910. *Bull. U. S. Nat. Hist. Mus.*, 100, *Vol. I, pt.* 4, 1919.

OYE, P. VAN. Unters über die Chätognathen des Java meers. *Contrib. Faune des Indes Neere Buitenzorg, IV*, 1918.

SANKARA MENON, K. A Preliminary Account of the Madras Plankton. *Records of the Indian Museum, Vol. XXXIII, pt.* 4, *Calcutta*, 1931.

VON. RITTER ZAHONY, R. Chätognathen. Ber. Comm. Erforsch Ostl. Mittelmeere., Zool. Ergebn., XIV, 1908.

——— Die Chatognathen der Plankton Expedition. *Plankton Exped. Humboldtstiftung, Bd. II*, 1911.



SAGITTA OF THE MADRAS COAST.